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Kurt Walter

Prosopis, an Alien among the Sacred Trees of South India

Prosopis, an Alien among the Sacred Trees of South India

Kurt Walter

Academic Dissertation

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ABSTRACT

The problematic of invasive species in an alien environment has aroused the attention of scientists all over the world for quite some time. One of the exotic tree species that has provoked special attention in the tropical drylands is *Prosopis juliflora*. Originating in South America, prosopis (hereafter referred to as prosopis) has been introduced in the hot and semi-arid zones of the world particularly to provide fuelwood, to stabilize sand dunes and to combat desertification. The tree has become an essential source for fuelwood and a provider of several other products and services in areas where it has become established.

However, despite the numerous benefits the tree provides to rural people, in several regions prosopis has become a noxious weed with a negative impact on the environment and to the economy of farmers and landowners. In India, prosopis was introduced in Andhra Pradesh in 1877. The tree was then proclaimed as the precious child of the plant world by scientists and local people alike.

The purpose of this study was to investigate the overall impact of prosopis on local rural livelihoods in the drylands of South India. Of particular interest was the examination of the different usages of the tree, especially as fuelwood, and people's perceptions of it. Furthermore, the study examined the negative impacts of the uncontrolled invasion of prosopis on croplands, and its occupation of the banks of irrigation canals and other water sources.

As another central theme, this study analysed the Hindu classification system for nature and for trees in particular. In India, several tree species are regarded as sacred. This study examined the position of the exotic prosopis among sacred trees, such as the bodhi, banyan and neem trees.

The principle method for collecting the field data was by using individual and thematic group interviews. These interviews were semi-structured with open–ended questions. Moreover, unstructured interviews as well as general observations provided complementary information. The data were gathered during two fieldwork periods in the states of Andhra Pradesh and Tamil Nadu, in South India.

The results confirmed that prosopis both provides benefits and causes hazards to different stakeholders. Farmers and agriculturalists suffer economic losses in areas where prosopis has invaded crop fields and competes with other plants for water and nutrients. On the other hand, for a significant number of poor rural people, prosopis has become an important source of livelihood benefits. This tree, which grows on government wastelands, is commonly a free resource for all and has thus become a major local source of fuelwood. It also provides several other goods and services and cash income that contributes to improve livelihoods in rural communities.

Prosopis ranked lowest in the tree classificatioin system of the Hindus of South India. Although it is appreciated for many benefits it provides for poor people, it has remained an "outsider" compared with the indigenous tree species. On the other hand, the most sacred trees, such as the bodhi or the banyan, are completely excluded from extraction and it is seen as a sacrilege to even cut branches from any of these trees. An unexpected finding was that, in a few cases, prosopis had also been elevated to the status of a sacred tree.

Goods and services from prosopis are not utilized in the most beneficial way. Silvicultural management practices are suggested that would provide additional income and employment opportunities. Interventions are recommended to control further invasion of the tree that might

cause serious negative effects in the future. For Hindus, the sacred always ranks highest, even above economic gain. The conservation of sacred groves and sacred trees is a tradition that has its roots in ancient history. These socio-religious practices need to be respected and continued. Successful management of tree and forest resources depends on the willingness of the local people to manage their natural resources, and this willingness exists – and has always existed – in South India.

Keywords: South India, drylands, livelihood, fuelwood, invasive, resource, silviculture.

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PREFACE

This study was carried out at the Viikki Tropical Resources Institute (VITRI). Two departments of the University of Helsinki were involved, The Department of Forest Sciences to which VITRI belongs, and the Department of Social Research (Social and Cultural Anthropology). My first field trip to India was funded by the Finnish Society of Forest Science. The same foundation also supported me with a grant at a later stage of this study. Additional financial support was granted by the Niemi Foundation and the Ella and Georg Ehrnrooth Foundation. I am grateful for all their support.

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I dedicate this thesis to my first grandchild, Thomas, who was born on the 27th of February 2010.

Helsinki, January 2011

Kurt Walter

TABLE OF CONTENTS

LIST OF TABLES, FIGURES AND BOXES

Tables:

Figures:

Boxes:

GLOSSARY OF SANSKRIT TERMS

Sanskrit words are written in *italics* with a small initial letter and diacritical marks have been applied to them. Sanskrit proper names like Rāmāyaṇa and Mahābhārata and works of literature like Arthaśāstra or Brahmāṇas are written with initial capitals and diacritical marks but are not italicized. Diacritical marks have been applied to all Sanskrit words which is the accepted method of transliterating the *devanāgārī* alphabet. They determine the pronounciation of vowels and consonants, for instance:

a	short like "u" in "luck"
ā	long "a" in "grass"
i	short like "I" in "sit"
ī	long like "ee" in "sweet"
n, ṇ	like "n" in "now"
ś, ṣ	like "sh" in "show"

Names where English spelling has become customary (i.e. Veda, Aryan), are written without diacritical marks.

abhayavana	Protected woodlands.
ākāśa	Space.
amṛta	Nectar of immortality.
ap	Water.
Āraṇyakas	"Forest books", dealing with the cosmic significance of the Vedic rituals; a category of Vedic literature, following the Brahmāṇas and preceding the Upaniṣads.
āratī	Cermonial waving of a lamp in front of an effigy of god as an offering of light during *pūjā*.
Arthaśāstra	A work on politics in theory and practice extolling law, order and centralized authority. The book is attributed to the Brahmin Kautilya who acted as a minister under the rule of Chandragupta Maurya (323-297 B.C.).
artha	Object of desire, material welfare.
Aryan	Noble; tribes that invaded India in the second millennium B.C.; created the Vedic civilization (Aryans).
Atharvaveda	The fourth Vedic collection of hymns also known as the "fourth Veda".
Brahma, Brahmā	The first of the Hindu Trinity (*Trimūrti*), the God creator; he was the chief God during the period of Brahmānism; in entire India, only two temples are dedicated to him (in Puśkara near Ajmere and in Khedbrahmā).
Brahmāṇas	Priestly literature, texts that follow the Vedas; treatises on mythological and cosmic significance. Most important is the Śatapatha Brahmāṇa.
Brahman, brāhmaṇa	
Brahmin, brāhman	Priest; member of the first of the hereditary castes (*varṇas*).
dharma	Righteousness, virtue, duty, moral order.
jīvanmukti	The condition of having attained enlightenment.
jīvanmukta	One who has attained the condition.

karma	Deed, action and its residues; the cosmic law of balance; a kind of natural "law of retribution" for human actions on the principle "as you have sown so you will reap".
ksatriya	Warrior or aristocrat; member of the second of the four main Hindu castes (*varṇas*).
Lakṣmī	*Viṣṇu's* wife; underwent many incarnations alongside him as *Sītā* with *Rāma* or *Rukminī* with *Kṛṣṇa.*As *Viṣṇu's śakti* she is the sustaining force in the universe.
liṅgam	Mark, sign, symbol; representation of *Śiva*.
Mahābhārata	The great epic of the Bharatas'also known as the longest epic poem in the world. It tells about the events before, during, and after the vicious war between the Kauravas and Pāṇḍavas. The epic deals with questions of morality and duty including the meaning of life and salvation, and explains the ways to achieve it.
mantras	Formulas of prayer.
nāga	Snake.
prakṛti	Cosmic matter.
prithvī	The earth; "the broad one".
Pṛthivī Sūkta	Celebrated hymn of the Atharva Veda.
pūjā	Ritual worship, ceremony.
pūjārī	Cermony master, often a temple priest.
Purāṇas	Religious works of Hinduism containing legendary and mythological versions of creation, history and the destruction of the universe.
Rāma	Prince and hero of the epic Rāmāyaṇa. Regarded as the seventh main incarnation of Viṣṇu.
Rāmāyaṇa	The epic tells the story of Lord Rāma and his wife Sītā that went into exile followed by Rāma's brother Lakṣmaṇa. The epic is composed by Vāmīki probably between 750 and 500 B.C.
rajas	Passionate activity.
Rigveda	The first Vedic collection of 1028 hymns codified around 1000 B.C.
śakti	Divine creative female force
Samaveda	The second Vedic collection (compiled around 900-800 B.C.).
Saṃhitā	Collection of metric texts (mantras).
sattva	Lightness, purity.
Śiva	Third member of the divine Trinity as God Destroyer (destroyer of illusion) represented by his form as Naṭarāja; Lord of the creative cosmic power and the mastery of reality characterized by yoga.
śrīvana	Forests that are locally managed and extracted for the wellbeing of people.
Śruti	That which was heard; revelation; the summary designation of scriptures which have the status of divine revelation in Hinduism, i.e. the four Vedas.
śūdra	The fourth and lowest of the traditional varnas; traditionally artisans and labourers.
sūrya	Sun
tamas	Heaviness, lethargy.
tapovana	Woodlands meant for contemplation; it is believed that the Upaniṣads and Āraṇyakas are written in these forests.
tejas	Flame, light, brilliance, vital power.

tulasī	Holy basil (*Ocimum sanctum*); considered the most sacred of all Hindu plants; found in almost every Hindu home or yard.
Upaniṣads	Philosophical discourses and mystical writings dating from approximately 800 B.C. and included in the Vedic literature as its end or closing part; believed to be composed out of divine inspiration.
Durgā	Hindu goddess.
vaiśyas	Third highest in ritual status of the four varnas; traditionally described as commoners.
varṇa	Sanskrit name for the original four Hindu castes; colour.
vāyu	Air.
Vedas	Knowledge; sacred scriptures of Hinduism, the oldest religious literature of India, including: Ṛgveda Saṃhitā, Sāmaveda Saṃhitā, Yaryuveda, and Atharvaveda Saṃhitā.
Viṣṇu	Member of the divine Trinity; as God the Preserver who sustains the creation.
Vṛkṣāyurveda	The Veda of plants and trees.
Yajurveda	The third collection of Vedic scriptures dealing with sacrificial procedures and formulae.

The sources used to compile this glossary were:

- Werner, K. 1997. A popular dictionary of Hinduism.
- Chapple, C.K. and Tucker, M.E. (eds.) 2001. Hinduism and ecology. The intersection of earth, sky, and water.
- Spoken Sanskrit Dictionary (online).

LIST OF ABBREVIATIONS

CAZRI	Central Arid Zone Research Institute
CBD	Convention on Biological Diversity
CEMDE	Centre for Environmental Management of Degraded Lands
CIFOR	Centre for International Forestry Research
CPR	Common Property Resources
DFID	Department for International Development
DGSS	Dashauli Gram Swarajya Sangh (Co-operative prganisation during the Chipko Andolan)
FAO	Food and Agriculture Organisation of the United Nations
FD	Forest Department
IFAD	International Fund for Agricultural Development
JFM	Joint Forest Management
MDF	Moderately Dense Forests
NTFP	Non Timber Forest Product
OP	Open Forests
PF	Protected Forests
RD	Revenue Department
RF	Reserved Forests
RWEDP	Regional Wood Energy Development Programme
SL	Sustainable Livelihood
SRL	Sustainable Rural Livelihood
UNCED	United Nations Conference on Environment and Development
VDF	Very Dense Forests

MEASUREMENTS

Rs	Rupees (Indian currency): 1 Euro (€) = 52.5 Rs; 1 USD ($) = 43.5 Rs (Exchange rate in July 2005); 1 Euro (€) = 67.5 Rs; 1 USD ($) = 48.5 Rs (Exchange rate in December 2008);
ha	1 ha (Hectare) = 10^4 m^2 = 2.471 Acres
quintal	1 quintal [metric] = 100 kilograms

Figure 1. Woman carrying *Prosopis* firewood.
(Photo: Kurt Walter).

1. Introduction

1.1. Culture and nature

This is a study of one species of tree, *Prosopis juliflora*, and its impact on the natural and social environment in two regions in India. The relationship between humans and nature is mediated by culture, symbolic behaviour. Culture adds value to life and the relationship between people and nature is always dynamic and interactive. Although nature, environment and ecological processes are known to us, whenever we come into contact with another culture the question arises, how do these people see nature and themselves as a part of it? When we are confronted with the way other people treat their environment and use natural resources, we are eager to compare it to the way we have learned to understand and handle those issues. The biological mechanisms of perception are not questioned, but the organization of experience, the training of the senses according to relevant social principles, varies from society to society. Thus nature is perceived according to the manners and customs of a particular society, according to their culture (Sahlins 1995). Therefore, empirical scientific descriptions are numerous because of their comparative value in understanding how particular cultures categorise nature.

The idea behind classification is to arrange things into groups that are distinct from each other according to particular relations that turn chaos into rational order (Lévi-Strauss 1966). For Durkheim and Mauss (1963), the model for a complex system of classification is the society itself, and the first logical categories were social categories. As human groups are related and fit into each other, like sub-clans into clans, clans into moieties, moieties into tribes, things in nature are ordered in a like manner.

Animals and plants do not need to be useful in order for people to study and classify them. Rather it is the other way around; because they are known, they are considered to be useful and worthy of note (Lévi-Strauss 1966). This is in contrast to the dominant Western way of perceiving nature. In Western culture things are seen through their use as utilities. In other words, things are perceived as a function of their capacity to do either good or evil to people (Sahlins 1995). Berman (1981) understands the native Western praxis theory of knowledge as the Cartesian or technological paradigm, the equation of truth with utility, where humans purposefully manipulate their environment to serve people. In contrast to the objective realism of Western science, a sensory epistemology or folk taxonomy is embedded in, and mediated by, the local cultural order. Folk taxonomy comprehends nature through human activities and relationships to it (Sahlins 1995).

The many small-scale societies in various regions of the world are dependent on nature and have developed a particular ecological sensibility adapted to their region. The way these societies use their resources influences the development of the society from within and their relations and interaction with other societies. Culture develops in response to nature and the ecological infrastructure of soil, water, and forests conditions the evolution and direction of economic life, politics and social structures. Humans use and try to form nature for their own best interests within the environmental limitations. But nature can only stay vital, keeping up the never-ending cycle of life-giving processes, when the exploitation of natural resources is not one-sided but a mutual give and take. There is a natural balance between the animal, plant and human environment where all the parts compete or co-operate for a place on the earth (Mukerjee 1930).

This balance has always been of great significance in India, where the population pressure, together with natural fluctuations caused by excess rain or drought periods, or continued human destructive actions like deforestation, overgrazing or unsustainable agriculture, led to a depletion of natural

resources. As a consequence, a continuously growing human population has had to make its living in a disturbed environment with rapidly dwindling resources. Trees and forests have always played a significant role in Hindu tradition. They were not only significant as a material resource but also as an object and a place of worship.

1.2. Resource use and its influence on ecosystems

In Indian culture when the beliefs about sacred nature and sacred trees were founded and passed along to following generations there was no scarcity of natural resources. In the traditional Hindu way, trees were utilized in a prudent way as medicines, fodder, or building material. Branches were pruned and used as important firewood. Animal husbandry was practised on higher altitudes and latitudes or in areas of lower rainfall where agriculture was not predominant. Pastoralists and nomads, who depend on natural plants and animals, used those resources in a specific way to ensure that a particular limited resource was only utilized by a particular lineage or caste group. The prudent exploitation of natural resources included a willingness to sacrifice the immediate use of a specific resource in hope of a greater benefit in the future. This would enable them to continue their traditional way of life in the coming generations (Gadgil and Malhotra 1998).

Issues and worries about environmental degradation and its devastating consequences for humans and nature arose when natural resources started to become scarce due to a continuously increasing population. Population pressure resulted in an ever-increasing need for natural resources, food, and grazing lands. The overexploitation of natural resources in India started with the advent of the British Empire. After British colonialists had gained political control over the country around the middle of the 19th century, they took over forests that were previously managed by the communities in order to extract the valuable timber they needed to build sleepers for railway lines and to produce charcoal for railway engines. The fuelwood consumption of the railways before the coal mines of Raniganj started to operate at an optimal level was considerable and caused a high degree of deforestation in the North Western Provinces during the 1880s. The progress of the railway network caused significant losses of tree cover if one considers that towards the end of the 19th century alone in the Madras Presidency more than 250,000 sleepers, equal to 35,000 trees, were required every year from local forests (Gadgil and Guha 1992). This period ended the traditional conservation of sacred trees and sacred groves (Gadgil 1984).

At the onset of the 19th century, most of the land in India was uncultivated. The land surrounding the villages was enough to provide the subsistence needs of people. Forests, usually inhabited by tribal groups, were concentrated in infertile highlands, remote from habitations. They were never over-exploited and the Indian rulers exempted the forest dwellers from taxation and concentrated more on taxing the fertile agricultural lands surrounding villages and towns. However, the presence of the British after the late 18th century brought significant changes in land and forest usage.

Because of the commercial interests of the British colonialists, they declared that forest lands were owned by the crown. Property rights were given only to lands under cultivation. Human resource use practises, like temporary or rotational swidden farming, the extraction of non-timber forest products (NTFPs), or grazing of livestock on forest lands, were restricted. By the beginning of the 20th century, around 20 million hectares of land was declared as Reserve Forests which could only be used by the Forest Department (Saxena 1997).

After people were restricted to enter state forests, they were forced to get their firewood from trees outside forests. Since those scarce resources were quickly exhausted, the British administration introduced new trees from other parts of the world that they thought would serve to satisfy people's need for fuel and fodder. After independence in 1947, the forests remained state owned and were managed to produce timber of economic value. The new government of independent India encouraged forest officials to continue planting and distributing seeds of the alien species, *Prosopis juliflor* (Sw.) DC., in order to substitute for the loss of fuelwood from the government-owned and managed forests (Murthy, personal communication).[1]

1.3. Consequences of changing patterns of land use

Land transformation is one of the predominant impacts that humans have on an ecosystem. Increasing urbanization, deforestation, and intensified agriculture on the one hand, and the abandonment of agricultural lands on the other, are human-caused land use changes which consequently result in either sudden or more gradual degradation of the ecosystem. While the negative impact from overgrazing might cause a rather gradual degradation, converting land for urban development or clearing land for agriculture can lead to a sudden change of the ecosystem. The introduction of new species, like plantation trees or trees and shrubs for forage, has also caused land use changes all over the planet. Together with inappropriate land use it can provide the necessary conditions for an invading species to become established (Hobbs and Mooney 2005).

Drylands are resilient ecosystems and capable of returning to their natural balance after the disturbance is over. The dynamism of those ecosystems allows species to come and go according to the current abiotic conditions, the grade and type of disturbance, and the composition of the species present. The increase of human disturbance of the ecosystem, combined with the increase of deliberate or accidental transfer of non-indigenous species, contains the potential to radically alter the ecosystem, making it vulnerable to changes in species composition. The above mentioned factors of disturbances in combination with climatic change increase the potential of invasion by non-native species, which, due to their wide ecological amplitude, are able to take advantage and colonize and expand their populations (Hobbs and Huenneke 1992).

People living in the drylands are especially dependent on the scarce resources that the ecosystem provides. Land degradation caused by overexploitation and abiotic changes affects especially poor and landless people due to the scarcity of their main livelihood supply. For most poor in the drylands, firewood is the only source of fuel to prepare their daily meals.

Livestock is especially dependent on fodder that has a high content of proteins. Degraded lands are not suitable for agriculture; since fertilizers are mostly unaffordable, there is a demand for crops or plants that suit the harsh environmental conditions of the drylands and serve people's needs to support their livelihoods. A suitable fodder plant should be able to survive the extreme climatic conditions of dryland ecosystems with minimum need for irrigation, should produce a high yield of biomass and quality proteins, and should have the ability to fix atmospheric nitrogen in order to improve soil conditions. The leguminous tree *Prosopis juliflora* exhibits these qualities and has gained the reputation among scientists as being an ideal crop for minimal energy input agriculture (Felker and Bandurski 1979; Singh 1996; Tewari *et al.* 2000).

[1] Ramana Murthy, Conservator of forests, National Forest Department (2005).

1.4. Problem statement and significance of the study

India was, and is still today, strongly influenced by the Hindu religion and its sacred literature, starting with the Vedas. For a Hindu, all nature is sacred and many forests and specific tree species are regarded as the abode of deities. Traditionally Hindus utilized trees and forests in a prudent way. In contemporary India, resources have become scarce and a growing population is increasingly dependent on dwindling natural resources. Initially, the exotic leguminous tree *Prosopis juliflora* was introduced into the drylands of India one-and-half centuries ago mainly for the purpose of conservation but has meanwhile become the main source of fuelwood in the rural areas, fulfilling more than 70 percent of the firewood requirements of rural people living in the areas (Reddy 1978; Harsh and Tewari 1998; Tewari *et al.* 2000).

Today, the tree has established itself, spreading all over the arid and semi-arid regions, and in some areas it has become an invasive weed. Although people are in great need of the resources that *P. juliflora* provides to them, they are still aware that it is a tree from outside India which has no roots in the indigenous environment. The invasion of the tree has caused harm and economic losses to various farmers and landowners while the poor and landless people in the rural areas depend in many ways on *P. juliflora* to support their livelihoods. The constellation of the alien invasive tree in an environment of sacred trees and forests, potentially supporting and threatening livelihoods, potentially greening degraded lands and suppressing biodiversity, was the challenge and motivation to undertake this study.

1.5. Aims of the study

The general objective of this study was to investigate and evaluate the impact of *P. juliflora* on livelihoods of people in the arid and semi-arid environment of South India, so as to provide scientific research-based guidelines for management of this resource.

The specific aims of the study were to examine and analyse the:

1. traditional Hindu classification of nature in general and trees in particular;
2. position of *P. juliflora* among sacred trees in contemporary Hindu society;
3. various usages of *P. juliflora* by different groups of people, particularly by farmers, labourers, and landless people;
4. opinions and perceptions of people about *P. juliflora* as a resource and/or threat; and
5. potential danger of further invasion of *P. juliflora* as well as the potential for utilization and controlled management of the tree.

An understanding of Hindu culture was the precondition to be able to understand how people perceive and utilize nature. The intention during the data collection was to see the problem through the eyes of the people who were involved in and supported this research, minimising the effect of the researcher's own cultural and religious background.

2. Literature review

2. 1. Prosopis juliflora

2.1.1. Nomenclature, habitat and growth

The genus *Prosopis* L. belongs to the family Leguminosae (Fabaceae), sub-family Mimosoideae. *Prosopis* contains 44 species, of which 40 are native to the Americas, three to Asia and one to Africa. In the Americas, Argentina has 28 native species, of which 13 are endemic (Table 1). The tropical Andean region is home to six species, and eight species are found in the Texas area, seven of them being endemic. Within *Prosopis* spp. there are trees and shrubs of varying size, mainly characterized by the presence of thorns and prickles (Burkart 1976).

Burkart (1976) described the *Prosopis* species as trees reaching a height of between 3 to 12 metres which can also appear as a shrub. In all species the wood is hard and the branches are spread, forming a round or flat-topped crown and green foliage.

Prosopis juliflora (Swartz) DC. is conspiciously thorny with a wide, flat-topped crown. In this species, are commonly smaller trees with prostrate forms that may develop upright stems when they mature. Thorns of this species vary from 1.2 to 5 cm in length and 3 to 6 mm in width; thorns can be found in pairs in leaf-axils or solitary. Prosopis[2] trees are evergreen and are partly deciduous only on very arid sites (Maydell 1986).

The leaves of prosopis are ample, glabrous or pubescent, and bipinnate with a length from 3 to 11 cm. Leaflets are in 12 to 60 linear pairs, with a size ranging from 6 to 23 mm in length and from 1.6 to 5.5 mm in width (Burkart 1976). Prosopis has flowers arranged in cylindrical spikes of 5 to 10 cm in length and 1.5 cm in width, situated in clusters in the leaf axils or solitary. Individual flowers are fragrant, small and densely crowded, and gold-yellow in colour. The pods are similar to bush beans, straw yellow in colour and 10 to 20 cm in length (Maydell 1986). Pods consist of an exocarp, a fleshy mesocarp and endocarps, divided into one-seeded coriaceus to bony segments. Each pod contains 10 to 20 hard seeds. The seeds are brown in colour, 7-8 mm long, longitudinal and fixed at the segment's distant angle (Burkart 1976).

The root system of prosopis consists of a deep tap root, sometimes reaching to the unusual depth of 35 m, combined with extensive lateral roots. Prosopis is especially suitable for dry sites with annual rainfall between 150 – 700 mm (Maydell 1986). Tap roots contribute to a stable anchoring of the tree and expand towards ground water reserves. They are essential during periods of drought when only deep water sources are available. The depth of the roots depends on the quality and structure of the soil and the availability of soil water; it is also determined by the density of the stand (Wunder 1966). Once the water source is reached, the roots extend horizontally in the direction of the water flow. *Prosopis* species are adapted to areas with low rainfall and long periods of drought once they are established and are able to tap groundwater or any other water source during the first years. The lateral roots play an important role during rainy seasons or periods of abundant water, for instance, in irrigated areas. The trees are also able to absorb moisture through their foliage during light rains or from dew or other atmospheric sources of moisture (Pasiecznik *et al.* 2001).

[2] In the following, prosopis stands for *Prosopis juliflora*. However, in all headings as well as Tables and Figures, *Prosopis* is capitalized and written in italics.

Table 1. The genus *Prosopis* L. without varieties (Burkart 1976).

I Section PROSOPIS	**Series Ruscifoliae**
	P. fiebrigii Harms
P. cineraria (L.) Druce	*P. hassleri* Harms
P. farcta (Solander ex Russell) Macbride	*P. ruscifolia* Grisebach
P. koelziana Burkart	*P. vinalillo* Stuckert
II Section ANONYCHIUMA	**Series Denudantes**
	P. calingastana Burkart
*P. Africana (*Guill., Perr., & Rich.) Taubert	*P. castellanosii* Burkart
	P. denudans Bentham
III Section STROMBOCARPA	*P. ruizleali* Burkart
Series Strombocarpae	**Series Humiles**
P. abbreviata Bentham	*P. affinis* Sprengel
P. burkartii Muñoz	*P. articulata* S. Watson
P. palmeri S. Watson	*P.campestris* Grisebach
P. pubescens Bentham	*P. elata* (Burkart) Burkart
P. reptans Bentham	*P. humilis* Gillies ex Hooker & Arnott
P. strombulifera (Lam.) Bentham	*P. pallida* (H. & B. ex Willd.) H.B.K.
*P. torquata (*Cavanilles ex Lagasca) DC.	*P. rojasiana* Burkart
	P. rubriflora E.Hassler
Series Cavenicarpae	*P. tamaulipana* Burkart
P. ferox Grisebach	
P. tamarugo F. Philippi	**Series Chilenses**
	P. alba Grisebach
IV Section MONILICARPA	*P. alpataco* R.A. Philippi
	P. caldenia Burkart
P. argentina Burkart	*P. chilensis (*Molina) Stuntz emend. Burkart
	P. flexuosa DC.
V Section ALGAROBIA	*P. glandulosa* Torrey
	***P. juliflora (*Sw) DC.**
Series Sericanthae	*P. laevigata (H.* & B. ex Willd.) M.C. Johnston
P. kuntzei Harms	*P. nigra* (Grisebach) Hieronymus
P. sericantha Gillies ex Hooker & Arnott	*P. pugionata* Burkart
	P. velutina Wooton

2.1.2. Global history of introduced *Prosopis juliflora*

Prosopis species, some of which are classified as woody weeds, can be classified into two categories: species that occur in their native range or those which have been deliberately introduced and grow and expand in exotic areas. The main countries that initiated introductions of *Prosopis* around the world over the last 200 years are Spain, Portugal, France and England. *Prosopis* spp. were introduced because of their usefulness to produce fuel, timber, food for humans and livestock, and many other products. Further, *Prosopis* spp. are relatively easy to establish in the dry arid and semi-arid areas of the tropical and semi-tropical regions. *Prosopis* is able to survive in the most inhospitable environment, on nutrient poor, saline and alkaline soils, and in hot climates. However, despite their usefulness to humans and animals, *Prosopis* species have shown to be highly invasive, particularly in exotic environments. They are capable of transfering fertile land into dense thickets of impenetrable tree stands (Pasiecznik *et al.* 2001; Pasiecznik *et al.* 2004; Pasiecznik *et al.* 2006a).

In the case of native *Prosopis* species, several are classified as noxious weeds in the USA, Paraguay and Argentina. There, *Prosopis* spp. have transformed millions of hectares of rangelands into impenetrable thickets. *Prosopis juliflora* is recorded as an alien species in 71 countries around the world (Haysom and Murphy 2003). In its native range, *P. juliflora* is commonly not classified as a weed, although it appears in dense thickets in areas of Central America and the Caribbean. However, areas of Columbia and Venezuela have declared *P. juliflora* a weed due to the invasion of the trees into their rangelands (Pasiecznik *et al.* 2001).

Globally, the four major successfully introduced *Prosopis* species are *P. juliflora, P. pallida, P. glandulosa,* and *P. velutina*. The first two species were mainly introduced in tropical regions, while the latter two were introduced in sub-tropical regions. *P. juliflora* has, however, become naturalized in several regions and continents. Introductions of *P. juliflora* have taken place in tropical regions of four continents: the Americas, Australia and the Pacific, Asia (particular India and Pakistan), and Africa including the Middle East. Of all introduced *Prosopis* species, *P. juliflora* performs significantly better than the other *Prosopis* species, especially in the dry tropics. But it is also the species that is most invasive in exotic environments (Pasiecznik *et al.* 2004).

However, scientists have clarified that in several countries, like Cap Verde, in north-east Brazil and Senegal, the invasive *Prosopis* is *P. pallida* and not, as earlier believed, *P. juliflora*. Other countries where *Prosopis* has been only recently identified as *P. pallida* are Kenya, Mauritania and India (Pasiecznik *et al.* 2006a).

Introductions in the Americas

The semi-arid zones of north-east Brazil are the major sites for the introduction of *Prosopis* in the Americas (Burkhart 1976; Pasiecznik *et al.* 2001). The first introductions occurred in Serra Talhada, Pernambuco, in 1942. It is assumed that today the entire population of *P. juliflora* in the north-east of Brazil resulted from only four trees that survived the second phase of introduction in 1947-48. The seeds that were sown in the area of Rio Grande do Norte originated from Peru and the introductions one year later from Sudan (Pires *et al.* 1990; Silva 1990).

Scientists assume that the introduction of *P. juliflora* into the dry coastal regions of Ceará and Rio Grande do Norte took place already in the 1800s due to the trade between Brazil and the Caribbean. There is a wide genetic diversity within *P. juliflora* in Brazil. Those first introductions are related to the thorny, slow growing type, while later introductions in the 1940s have their origin in the

Peruvian-Ecuadorian race. Those later introductions are fast growing with erect form and short thorns. Today, this is the dominant type found in the north eastern parts of Brazil (Pasiecznik *et al.* 2001).

Probably during the times of the spread of human settlements across the American continent, the introduction of a variety of *Prosopis* species took place in several countries, like for instance in Peru, Chile, the Pacific coast of Central America, and the Caribbean. During recent decades, several *Prosopis* species have been introduced into the dry zones of Texas and California in the USA (Pasiecznik *et al.* 2001).

Introductions in Australia and Hawaii

The introduction of *Prosopis* species in Australia started in the early 1900s. The main purpose for sowing the species was the use as shade trees around homesteads and the use as a possible food source for livestock. Already in the 1920s and 1930s, the species were widely distributed throughout Queensland, which is situated in the Northern Territory of Western Australia. After an initial slow spread, the floods that occurred in 1945 initiated a rapid invasion of the trees. A few *Prosopis* trees, planted in the 1930s around a homestead in Western Australia multiplied at such a speed that it resulted in the largest *Prosopis* infestation in Australia. By the onset of 2000, those few trees multiplied to an area of 30.000 ha of dense *Prosopis* stands (Osmond 2003). *Prosopis juliflora*, introduced from Mexico, has spread throughout the country only on a limited scale. Commonly, the most widespread infestations are of the species *P. pallida, P. glandulosa* var. *glandulosa*, and *P. velutina* (Csurhes 1996).

Burkhart (1976) mentions an increase of *P. juliflora* on the Hawaii islands where the species has become naturalized. It is assumed that the seeds originated from Peru and the Pacific coastal areas of Central America. However, it has become evident that it is *P. pallida*, which is morphologically similar and often incorrectly identified as *P. juliflora*, that actually dominates the coastal areas of Hawaii. The first introductions of both of the species date back to 1838, when Father Alexis Bachelot, from the Catholic Missionary Society, initiated the plantations. The seeds are known to belong to a native *Prosopis* species from Brazil (Esbenshade 1980).

Introductions in Africa and Yemen

There are several species of *Prosopis* that have been introduced in Africa and have become noxious weeds. However, only *P. Africana* is native to the continent and can be found in Senegal, in regions from Guinea-Bissau to Nigeria, in Cameroon, in Sudan, Uganda and in Ethiopia (Burkhart 1976). The species is highly appreciated among people in many ways. The seeds are used to prepare traditional food, leaves and pods are used as livestock feed, and its hard wood is used for many purposes. *P. Africana* is also one of the most valuable agroforestry species which is seriously threatened in the semi-arid lowlands of Western Africa (Tchoundjeu *et al.* 1998).

However, a number of other introduced *Prosopis* species have become noxious weeds in many arid and semi-arid regions of Africa. Several species were introduced into South Africa during the 1880s, when landowners were encouraged by government agencies to plant *Prosopis* on a wide scale. Among the most common species introduced were *P. pubescens*, *P. juliflora*, *P. chilensis*, *P. glandulosa var. glandulosa*, *P. glandulosa var. torreyana* and *P. velutina* (Pasiecznik *et al.* 2006a). Many of the *Prosopis* species were thought to be *P. juliflora*, but certainly contained *P. velutina* and

all the varieties of *P. glandulosa*. *Prosopis* was perceived as a valuable wood resource until the 1960s, when infestations of the trees appeared on a large scale and it became clear that conventional methods of controlling further invasions were insufficient. Today, it is mainly *P. velutina* and *P. glandulosa var. torreyana* that have invaded drylands on a large scale. Both species including their hybrids are categorized as invaders (category 2) under the Conservation of Agricultural Resources Act, 1983; Act No. 43 of 1983 (CARA 1983). Meanwhile, it has become very difficult to classify *Prosopis* because of hybridizations among all the introduced species. It has become obvious that the hybrids have become more invasive than their original parent species (Pasiecznik *et al.* 2006a).

In Egypt, *Prosopis* was planted in the early 1900s and was identified as *P. juliflora*. However, the species was only able to survive in sheltered areas that are not exposed to cold temperatures. Most trees of *P. juliflora* grow in the south of the country, where frosts do not appear. It is commonly *P. velutina*, *P. chilensis* or *P. glandulosa* and their hybrids that form thickets in the Mediterranean Zone of North Africa (Pasiecznik *et al.* 2001).

Many countries of eastern Africa have suffered infestations of *Prosopis* in recent years Sudan being one. *Prosopis juliflora*, or mesquite as it is called by Sudanese people, was introduced in the Sudan in Khartoum in 1917, using seeds purchased from Egypt and South Africa. In the 1930s, the introduction of the trees continued into central Sudan, and to various other parts of the country like the Gezira Agricultural Irrigation Scheme, to Port Sudan, and to Darfur in western Sudan. In 1947, and later in 1965, *P. juliflora* was introduced in the green belt around Kassala and in the New Halfa Agricultural Scheme (ElFadl 1997; ElSiddig *et al.* 1998; Pasiecznik *et al.* 2001).

Meanwhile, mesquite has invaded large areas of irrigated farmlands, degraded and abandoned lands, watercourses, floodplains and highways. In 1995, the Government of the Sudan prohibited any further plantating of *Prosopis* trees (ElSiddig *et al.* 1998). By 2006, the infestations of *P. juliflora* in the Sudan cover an area of approximately 230.000 ha (Babiker 2006).

The introduction of *P. juliflora* into Ethiopia took place in the late 1970s in Dire-Dawa, with seeds possibly derived from India. Introductions in the north of the country, in Afar, are believed to have been undertaken by workers of the Middle Awash irrigation project in the late 1970s and early 1980s, with seeds either from Dira-Dawa, from Kenya, or from the Sudan. Meanwhile, *Prosopis* is continuously invading areas of the pastoralists of the Afar and Isa groups in the Afar National Regional State (ANRS) and has infested areas that are hundreds of kilometre away from its original introductions (Shiferaw *et al.* 2004). Other introductions over large areas in Ethiopia took place as part of the Food for Work Programme which lasted until 1988. Even today, *Prosopis* spp. are planted as shade trees and for living fences (Sertse and Pasiecznik 2005).

In Ethiopia's neighbouring country, Eritrea, the introduction of *P. juliflora* probably took place during the 1980s, however, not earlier that the 1970s. It is also not quite clear from where the introductions took place. It is assumed that *P. juliflora* was brought into the country by livestock from the neighbouring country, Sudan. There are close trading links between the Kassala State in the Sudan and the nearby neighbouring towns in Eritrea. Another possible place of entrance of the species into the country is assumed to be from the Afar region of Ethiopia. Meanwhile, *P.juliflora* has become a noxious weed in many of the dry areas of the country (Bokrezion 2008).

Although the time of the introductions of *Prosopis* spp. into most African countries can only be estimated, in the case of Senegal, the exact time of introduction is known to be 1822, with seeds from the Americas (Pasiecznik *et al.* 2001; Choge and Pasiecznik 2005). It is assumed that seeds of *Prosopis* spp. entered into Nigeria and Kenya from other African countries. However, the time of

the main introductions of *P. juliflora* into Kenya is dated to the 1970s and the 1980s with introductions promoted by NGOs, conservation agencies, and government departments (Choge and Pasiecznik 2005). The main motivations behind these introductions were the prolonged periods of drought in the 1970s which led to a severe loss of vegetation. Concerns about shortages in fuelwood supply created an urgent need for land rehabilitation with trees that are drought tolerant. *Prosopis* seemed to be the ideal tree species to serve this purpose (Choge and Pasiecznik 2005; Mwangi and Swallow 2008).

Latest research, using satellite images and field surveys, indicates that *Prosopis* invasions in Kenya threaten areas in the range of 27.7 million ha in the worst case scenario. The particular area under research did not show any appearance of *Prosopis* in 1990. In 1998, the same region showed infestations covering 5 percent and in the latest study, *Prosopis* had increased to 39 percent of species occurrence (Muturi *et al.* 2009). In Kenya, *P. juliflora* is the most aggressive invader among the *Prosopis* species that occur in the country.

Two *Prosopis* species, *P. juliflora* and *P. chilensis*, were introduced into Yemen in 1974 for the purpose of combating soil erosion. There are mainly three areas that are heavily infested with *Prosopis*: one is the surrounding area of Aden, where *P. juliflora*, was observed already at the beginning of the 19th century, another is the Hodeidah Governorate, and the third is Hadramut (Ali and Labrada 2006). In many other areas of the Middle East, it is assumed that *P. juliflora* and *P. glandulosa* were introduced during the 1950s (Pasiecznik *et al.* 2001).

Introductions in South Asia (India, Pakistan and Sri Lanka)

The first introductions of *P. juliflora* into India took place in 1877, with seeds from Jamaica that arrived in the country one year earlier. The seeds were first sown in various arid areas around Kamalapuram, in the Cuddapah District of Andhra Pradesh, in South India. At the time of its introduction, the plant was named "the exotic lady of South America" (Reddy 1978). In the same year (1877), *P. juliflora* was sown in Sindh (Pakistan) to prevent sand dune encroachments. A few years later, additional introductions of *P. juliflora* took place in other regions of western India (today Pakistan), like the arid areas of the Lahore, Montgomery and Multan Districts and including small areas in the Jullundur District (Raizda and Chatterji 1954).

Prosopis juliflora was introduced in Jodpur (Rajasthan) in 1913 and in 1940 it was named a "Royal Plant", by the ruler of the state at that time, because of the excellent growth-rates of the plant. Further introductions followed gradually into the states of Haryana, Punjab, Uttar Pradesh, Madhya Pradesh, Maharashtra and Tamil Nadu (Harsh and Tewari 1998; Muthana 1985). Although the initial plantations in India were mainly established for the purpose of conservation, prosopis has become the main source of fuel in rural areas and today, also to a large extent, in urban and semi-urban areas. Today it fulfils more than 70 percent of the firewood requirements of the rural people in the tropical arid and semi-arid regions of India (Harsh and Tewari 1998).

Despite the introductions of *P. juliflora*, Raizda and Chatterji (1954) reported the introductions of other *Prosopis* species which they described according to their forms and linked them to the countries of their origin. Raizda and Chatterji (1954) named four of the species, the Mexican, Argentine, Australian and Peruvian forms. Additionally, a fifth species was named the Arid form without linking it to any country of origin. Pasiecznik *et al.* (2001) later identified the neutral Arid form species as being probably *P. laevigata, P. velutina* or a hybrid of them, through studying the forms of pods and leaves. The Argentine form was identified as *P. alba*, or a hybrid of it. The

Mexican form shows similarities with *P.juliflora* while the other two species, named as the Australian and Peruvian forms, could be classified as either *P. juliflora* or *P. pallida* because they exhibit characteristics of both species.

The common *Prosopis* species in Sri Lanka has been identified as the invasive *P. juliflora*. It is assumed that the first introductions of the species took place in 1880, with seeds from India, and introduced by the British, who ruled both countries at the time. In the 1950s, the same species was planted in a wide range in areas around Hambantota, situated in the southern provinces. Probably the trees were planted intentionally on infertile saline soils because the species was known to be salt-tolerant. However, there is no clear evidence and it might be possible that the plant was spread through livestock or through seeds that were carried by sea to the shores were it established itself. By now, *P. juliflora* is established and naturalized in the Hambantota district and the Puttlum District in the north central province (Perera and Pasiecznik 2005; Perera *et al.* 2005).

2.1.3. Biological and ecological traits of *Prosopis* that promote invasions

Due to their broad ecological amplitude, prosopis trees have adapted to a wide range of different types of soil and sites and are able to survive on the poorest lands which are unsuitable for many other tree species. The tree can be found on various soil types from pure sandy soils to heavy clay and stony soils. The most abundant prosopis trees are found in their native range at altitudes below 200 m but they can frequently establish themselves up to 1,500 m of elevation (Maydell 1986).

Prosopis species are able to survive and grow in alkaline and saline soils with a level of salinity equal to sea water (Felker *et al.* 1981). The optimum temperature for the growth of prosopis is between 20 - 30º C. In Asia, introduced prosopis is known to tolerate shade temperatures of more than 50 º C, which are rarely recorded in its native range. However, temperatures slightly below zero can harm the branches and cause the death of the tree when harder frosts appear or last for some time (Felker *et al.* 1982). In a trial in the Republic of Cap Verde, prosopis and several other multipurpose trees were grown under extreme arid climatic conditions with very low and variable rainfall, strong salt-laden winds, and soils with high salinity. Prosopis survived and outgrew all other species and even withstood goats browsing on the leaves and pods. The tree, thus, revealed its potential to produce firewood and bear fruits for fodder even under the most extreme climatic circumstances (Pasiecznik *et al*. 1995).

Prosopis trees are able to out-compete the indigenous vegetation and spread rapidly, in the worst case becoming agricultural weeds. Geesing *et al.* (2000) suggest that the woody legumes of *Prosopis* species have a competitive advantage on soils with low levels of nitrogen, creating islands of fertility through N fixation. Thus, for instance, under the influence of overgrazing, eroded and degraded poor nitrogen-deficient soils give prosopis seedlings a competitive advantage. The dominant factor that is responsible for the spread of *Prosopis* species is the interaction between climate and land use. Livestock rearing causes a reduction in, or even destroys, herbaceous competition, which is the cause for the decline of soil nitrogen levels. The widespread seed dispersal by livestock creates conditions where the expanding prosopis seed bank only needs to wait for favourable conditions to germinate and establish a new stand (Pasiecznik *et al.* 2001). In the Indian state of Gujarat, prosopis is the predominant species and an aggressive coloniser in places where sufficient soil moisture is available. In areas with adequate rainfall tree densities exceed 2000 individuals/ ha (Harsh and Tewari 1998).

In order to survive competition, environmental stress, predation or disease, plants exhibit numerous reproductive characteristics with the aim of maximising the chances of the progeny to survive. Part of the resources in the reproductive strategy are allocated to balance between sexual and vegetative reproduction, the production of an optimum number of seeds of optimum size, and fruiting at the most appropriate time (Fenner 1985). Seed size is probably a compromise favouring small seeds for a strategy that leads to wide areal dispersal or large seeds for more successful seedling establishment. Research has revealed that most invasive or weedy plants favour the production of small seeds, which leads to success when struggling for space. It is also suggested that production of small-size seeds is a strategy to escape predation (Fenner 1985).

Many plant species produce seeds that are adapted for endozoochory, seed dispersal via ingestion by animals (Fenner 1985). Prosopis produces a large number of small-size seeds (23 +/- 4 seed/ pod with a mean weight of 0.0275 g), which are adapted for endozoochory. The seeds passing through the guts of animals receive treatments that facilitate germination. The faeces itself probably acts as fertilizer in the critical phase of the establishment of the seedlings. The dispersal of the seeds in the faeces also occurs at some distance from the mother plant, which allows dispersal over a wide terrain (Shiferaw *et al.* 2004).

The dynamic vegetative reproduction, in combination with small seeds and short juvenile periods, are indications that a species will be a strong and competitive invader (Kolar and Lodge 2001). A short juvenile period, together with the remarkable coppicing ability of resprouting and fast coppice growth from stumped or damaged trees, give prosopis a considerable advantage over other plants in the competition for space (Shiferaw *et al.* 2004).

Another obvious advantage of exotic plants in competing over space with native plants is the reduced exposure to natural enemies. The enemy release hypothesis (ERH) states that the introduction of alien plants into a new environment favours exotics over native plants because alien species experience a decrease in regulations from natural enemies. This again enables exotic plants to increase in abundance and in distribution. Several studies directly link both the enemy release hypothesis (ERH) and climate change with the success of alien invasive plants (Keane and Crawley 2002). There is no specific study at the moment on how those factors affect prosopis. Plants need to allocate limited resources for growth, reproduction and defence from enemy attacks. The so-called resistance-costs commonly result in a decrease of fitness of the plant (Strauss *et al.* 2002). Thus, the absence of host specific enemies of prosopis in its exotic environment, in combination with climate change and increasingly disturbed environments, gives the plant several advantages to out-compete native species and further increase in abundance and space in the future.

Germination is the critical stage in the life cycle of plants. It happens usually at a time when seedlings find conditions to survive. *Prosopis* species accumulate a high density of seeds in various layers of the soil for long periods, enabling them to regenerate in the event of disturbance. Research has revealed that in non-saline habitats, temperature is not a limiting factor for prosopis seedlings to germinate if moisture is available. Light in interaction with temperature usually regulates seed germination. In laboratory studies, a temperature span between 15 and 25 °C did not indicate any significant difference while at 40 °C germination was higher in light than in darkness, particularly in fresh seeds that matured during autumn and winter. Light is abundant only on the soil surface, which suggests that seeds in upper layers of litter have a better chance to emerge than those from below. The seeds in deeper layers thus remain dormant, acting as a reserve during times of scarce rainfall (El-Keblawy and Al-Rawai 2005, El-Keblawy and Al-Rawai 2006).

In the Sultanate of Oman, in order to find reasons for the capability of alien *P. juliflora* to outcompete native plants, seedlings were tested by simulating various environmental conditions and comparing them with seedlings of indigenous *P. cineraria*. Immediately after sowing, seeds of *P. juliflora* germinated in 11 days, while *P. cineraria* initiated germination only after three to four weeks. Further, in simulated stress occurrence (dry-heat treatment), the germination rate of the former was significantly higher than in *P. cineraria*. Under drought stress, *P. cineraria* reduced substantially the weekly shoot relative growth rates (RGR/week) compared to unstressed conditions. This was partly caused by a highly reduced leaf area. On the other hand, drought stress had no major influence on shoot RGR/week of *P. juliflora*. The mortality of seedlings was also considerably lower in *P. juliflora* (5 percent compared to 41 percent in *P. cineraria*) in drought stressed conditions (Al-Rawahy *et al.* 2003). These investigations revealed a significant difference in germination when both species were placed together. While the germination rate of *P. cineraria* was 6 percent; *P. juliflora* produced 73 percent germinated seeds. The results suggest that the reason for this outstanding difference is due to the existance of alleochemicals in *P. juliflora* that prevent germination and growth in other plants that grow in close proximity (cf. also Warrag 1995).

Noor *et al.* (1995) discovered allelochemicals in prosopis, suggesting that these phytotoxins contribute to the superior success of the species in the competition with neighbouring plants. The extracts from fruits and seeds exhibit great phytotoxicity which inhibits the growth of neighbouring plants, restraining their rate and percentage of seed germination, seedling growth, as well as shoot and root growth. In another study, the inhibition of seed germination and early growth of Bermuda grass (*Cynodon dactylon* (L.) Pers.) was suspected to be caused by the water-soluble allelochemicals in nearby prosopis foliage (Al-Humaid and Warrag 1998).

The ecological advantages of prosopis compared with many native species and the resulting invasion of the tree causes a reduction in biodiversity of the native flora. Research has revealed that underneath prosopis canopies, the number of species and the evenness, frequency and density of indigenous species are significantly lower compared to the situation in open space. However, the number of seedlings of those native plants that are found is higher under the prosopis canopy than away from it. The soil fertility also seems to be significantly enhanced beneath prosopis canopies. Such observations have led to the conclusion that allelopatic inhibitions by prosopis are the reason behind the suppressive effect of this species on the indigenous plant biodiversity (El-Keblawy and Al-Rawai 2007).

In its native environment, prosopis is not invasive but is controlled by its natural enemies. As suggested above, one of the strategies that grant success for an alien plant in new habitats is due to its allelopathic effect. While in its original natural surroundings of an alien species the neighbouring plants have adapted to the chemical composition of its toxins, in another plant community no defence mechanism has developed against the release of harmful chemicals by the alien plant. Thus, the competitive mechanisms of the invaders disrupt inherent interactions that have developed during the evolutionary process of long-term coexistence among native plants (Callaway and Aschehoug 2000; Callaway *et al.* 2005). It is possible that, over a long time frame, native plant communities develope resistance to invaders that allows them to coexist and control the newcomer.

An analysis of plant and soil characteristics has revealed that *P. cineraria* exhibits a higher degree of correlation between leaf and soil characteristics than *P. juliflora*. The concentrations of leaf K (a suitable discriminator between the species), was found to be linked in the former species with the availability of the nutrient, whereas *P. juliflora* developed a relatively higher K concentration in its leaves. The uptake of K in *P. juliflora* was not dependent on the level of the nutrient in the soil. This suggested that the higher uptake of K in *P. juliflora*, together with a faster turnover of its leaf

material, can decrease the risk of soil K losses caused, for instance, by water logging and leaching. Thus *P. juliflora* accumulates K through leaf litter in the upper soil layers, especially under arid conditions. The same studies indicated that while nutrient concentrations were significantly higher in *P. juliflora*, the leaflet specific weight (LSW) was significantly lower in this species compared to *P. cineraria.* There was no correlation of LSW with any soil characteristic, which implied a higher capacity for photosynthesis in *P. juliflora* (Sharma and Dakshini 1998).

Prosopis juliflora has an advantage when competing with indigenous plant habitats.This advantage is caused by its ability for high uptake of nutrients independent of soil conditions and a minimum level of correlation between soil nutrient levels and plant characteristics. The species can thus function and satisfy its needs across a wide range of environmental conditions. Adding to this, compared with *P. cineraria*, *P. juliflora* exhibits low xylem water potentials in unstressed plants, keeping up a higher stomatal activity also under stress conditions. *P. juliflora* shows resilience by quick recovery after shedding off its leaves during drought and by quickly maximising its growth when conditions are again favourable (Harris *et al*. 1998).

Prosopis exhibits a prodigal, non-conservative water use pattern, consuming the maximum amount of water available in the soil. ElFadl and Luukkanen (2006) argue that introduced prosopis has not developed mechanisms that allow the species to overcome long periods of drought stress because of its profuse water use and the inability to control transpiration. The conclusion is that prosopis is able to become an aggressive invader only in areas with a sufficient water supply. Personal observations from the Sudan and South India indicate that prosopis has an overwhelming advantage over any other species when growing near water sources, like in irrigation schemes or around water tanks. However, even in the most drought-affected areas, it appeared that prosopis was able to colonise drylands.

Many theories have been developed for explaining the reasons for successful invasions of alien species. The main hypotheses for the success of alien plants in their new habitats are summarized by Hierro (2005) as follows:

Hypothesis	Definition
(1) Natural enemies	Exotics are released from natural enemies that control their population growth
(2) Evolution of invasiveness	Exotics experience genetic changes linked to new selection pressures in the novel environment
(3) Empty niche	Exotics utilize resources unused by the local species
(4) Novel weapons	Exotics bring novel ways of biochemical interactions to recipient communities
(5) Disturbance	Exotics are adapted to type and intensity of disturbances that are novel to natives
(6) Species-richness	Species-rich communities are more resistant to invasion than species-poor communities
(7) Propagule pressure	Variations in levels of invasion among recipient communities are due to differences in the number of exotics arriving in the communities

Probably there is not only one but a combination of various ecological strategies that lead to the success of prosopis as an invasive species in a novel habitat. In order to test the first four hypothesises above, there needs to be comparative biological studies of a particular species, both in its native and new exotic environment (Hierro 2005).

2.1.4. Potential of *Prosopis* in rehabilitating degraded soils

The need for low energy input agriculture is growing in the dryland areas of tropical countries. High costs of energy, in the form of nitrogenous fertilizers, water pumping systems or the use of tractors, have turned the focus towards plants with inherent physiological, ecological and morphological qualities that reduce the need for irrigation and fertilization while still producing high yields of protein-rich food and feed. A low content of organic matter in arid soils and a lack of soil nitrogen are believed to be limiting factors for growth in semi-arid climates.

In rainfed agriculture, leaves from multipurpose trees are traditionally one of the main sources of nutrients that maintain soil fertility. It has been suggested that the use of tree legumes, such as prosopis, has potential for a minimal input farming system because prosopis has the ability to grow with little or no irrigation, produces high yields, is able to fix nitrogen, and produces large amounts of high quality protein (Felker and Bandurski 1979). However, there is competition between trees and crops for water, nutrients, and light. Another point to consider is the number of years it takes before a constant improved soil status is reached for agricultural crop cultivation (Snapp *et al*. 1998).

A widespread traditional practice in the semi-arid tropics is to grow trees scattered or dispersed on croplands, known as "parklands". The degree of interaction between trees and crops depends on the density of trees. Trees in this system are rarely planted but occur and regenerate naturally. Farmers maintain these trees on their lands to provide fodder, fuelwood, timber and non-wood products (Rao *et al*. 1998). The improvement of soil properties comes as a side product, along with the provision of shade for people and livestock.

Farmers practicing intensive agriculture in South India frequently practice boundary tree planting. Prosopis, which is planted and managed deliberately, is the most common species for this purpose. Farmers plant prosopis hedges mainly for the purpose of protecting their fields from animal encroachment without being aware of the positive influence of trees on soil fertility and biomass production (personal communication). The area where trees and crops are grown together can be divided into three zones:

1. A zone under the tree crown where competition for light and root space takes place;
2. An area further away from the tree crown with root competition; and
3. The open crop area where trees and crops are free from interaction.

The influence of trees on crop yields depends on many factors, starting from tree species, the size of trees, and their density. However, an increase in crop yields due to soil fertility improvement takes many years to develop (Rao *et al*. 1998). In the case of crop failure due to drought, tree products can reduce farmers' risks. The competition between trees and crops can also be managed through pruning practices, such as the maintenance of an appropriate density and regular thinning.

The use of livestock manure is known to be beneficial for soil fertility management in tropical countries. It was estimated in the early 1970s that about 6 million tons of cattle dung and agricultural refuse, that had been used as fuel, was freed for use as manure because it was replaced by prosopis as fuelwood (Reddy 1978).

Along the coastline of South India, huge areas of land are degraded, lowering the productivity of farming due to natural or anthropogenic factors. Some factors that lead to, and enhance, land degradation are water erosion, salination, alkalization, and processes linked to mining activities. Soils that are affected by high concentrations of salt negatively affect the growth of crops. They are classified as saline, saline-sodic, and sodic soils, and are characterized by specific pH, EC[3], and ESP[4] values. Saline and sodic soils are characterised by high pH and high amounts of exchangeable sodium adsorbed to the soil particles in comparison to other cations such as Ca, Mg, and K. Because of high Na/Ca and Mg/Ca ratios, a reduced amount of Ca uptake in plants is a limiting factor for crop growth. The limited availability and uptake of nitrogen and micronutrients by plants is also attributed to sodic soils, as is low soil organic matter content (Lal 2006).

Prosopis is potentially useful for rehabilitating[5] degraded saline soils in dryland ecosystems where degradation is enhanced by high temperatures and irregular precipitation. Prosopis planted on degraded sodic soils increases soil fertility through adding to and increasing the soil organic C, nitrogen (N), available phosphorus (P) exchangeable potassium (K), calcium (Ca), and magnesium (Mg) levels. In addition, decreases in the exchangeable sodium level (Na), pH and EC can be observed. These processes have a positive effect on the rehabilitation of sodic soils through the improvement of nutrient cycling and detoxifying sodicity. As an effect of prosopis, the crop productivity tested on wheat indicated higher germination, survival, plant growth and grain yield (Bhojvaid and Timmer 1998).

In another field study, the performance of prosopis plantations in rehabilitation of saline-sodic soils showed the ability of the tree to reduce EC and ESP significantly compared to fallow land. The infiltration rate increased by 100 percent during a period of seven years, with a slight improvement of biomass accumulation, compared to barren (fallow) land. After seven years the soil was rehabilitated to a state where agriculture was possible again (Maliwal 1999). The influence of prosopis on alkali soils under irrigation and rainfed conditions revealed a stronger regeneration effect on soil qualities when irrigation water was supplied. Biomass production was up to three times higher on irrigated land. Irrigation also caused more significant reductions in pH and EC, as well as greater improvement in organic carbon and available nitrogen, and a considerable increase in water infiltration (Singh *et al*. 1996).

Research in various parts of the tropical arid and semi-arid zones has shown the usefulness of different *Prosopis* species in rehabilitating and protecting various soil types to a state where agricultural practices can be successfully re-introduced. There is still another rather serious challenge in soil remediation that needs to be confronted. India's increased industrialization and urbanization causes a heavy utilization of natural resources due to a fast growing population. Mining, smelting works, industrial and agricultural waste disposal leave behind heavily polluted lands that have become non-arable. Only plants that have the ability to tolerate high metal concentrations are able to grow on metalliferous soils. Those plants have a capacity to accumulate heavy metals (Prasad 2007). In such situations, phytoremediation has become a promising science to be used for cleaning up polluted and contaminated environments.

[3] EC stands for electronic conductivity, measuring the total amount of soil ions of a soil water extract.
[4] ESP stands for exchangeable sodium percentage.
[5] Rehabilitation refers to repairing damaged ecosystems with the aim to restore or increase productivity.

In vitro phytoremediation of heavy metal contaminated soils

Phytoremediation is a method to remove or render harmless environmental contaminants through the use of green plants. It refers to all chemical, physical, and biological processes in plants that aid in remediation of contaminated substrates (Cunningham and Berti 1993). Theoretically, phytoremediation uses agronomic techniques to restore[6] the contaminated soil by removing chemical and physical limitations to plant growth. The technique uses plants grown on contaminated soils for a specific time thus removing the pollutant from the soil through accumulating it in different parts of the plant or altering the chemical and physical structure of the pollutant in the soil so that it is not a risk to human health (Cunningham and Ow 1996).

The basic processes through which plants remediate metal-contaminated soils are:

- Phytoextraction → plants extract metallic and organic compounds from the soil and accumulate them in their tissues;
- Phytostabilization → reduction of the mobility of heavy metals within the soil through heavy metal tolerant plants, reducing the risk of leaching into the groundwater which would cause additional degradation;
- Rhizofiltration → absorption, precipitation, and concentration of toxic metals from polluted sewage through plant roots (Salt *et al.* 1996).

The use of trees to remedy heavily metal-contaminated soils has proved to be a sustainable, low cost method. Various tree species have shown a remarkable ability to take up and tolerate high concentrations of heavy metals. Trees are also able to produce large amounts of biomass which adds additional benefits; this occurs also through the use of the trees after they are removed from the land. A massive root system in trees can help to stabilize the soil while the above-ground growth forms a canopy that protects the soil surface from wind and water erosion (Pulford and Dickinson 2006).

Coimbatore, an industrial city in Tamil Nadu, is a centre of textile and metal-based industries. Many operations use coal for energy, with the result that there is an accumulation of heavy toxic metals in soils around the industrial factories. Among other plants, prosopis, the dominant species invading the wasteland around the area, was collected and analysed. The result of the analysis revealed a high capacity of prosopis to accumulate heavy toxic metals occurring in the soil (Senthilkumar *et al.* 2005). Prosopis is also able to accumulate lead (Pb) in various parts of the plant. The highest concentration of lead is found in the leaves, lower levels in the bark, and the lowest levels in the pods. The lead content in the plant can be used as an indicator to measure air pollution derived from industrial factories and vehicles (Bu-Olayan and Thomas 2002). Because of the high amounts of heavy metals accumulated in prosopis leaves and pods, it is recommended to keep livestock away from grazing on this species when it grows in heavy metal-polluted soils (Senthilkumar *et al.* 2005).

The combustion of coal in thermal power plants results in the accumulation of large amounts of fly ash. In India alone, 60 million tonnes of fly ash is produced annually and unmanaged ash disposal possesses a health risk. It has a negative impact on surface water and groundwater and limits visibility in the surrounding areas. Phytoremediation is used to re-vegetate and clean up fly ash landfills. Prosopis has shown potential to accumulate in its tissues the metals contained in fly ash. Inoculation of prosopis with fly ash-tolerant rhizobium (PJ-1) accelerates the translocation of metals from the soil to the above-ground growth. Rhizobium inoculation also increases the biomass of the

[6] Restoration: to return a habitat or ecosystem to a condition as similar as possible to its pre-degraded state.

plant in nitrogen deficient fly ash, which confirms that prosopis is beneficial for re-vegetation and decontamination of soil and landfills affected by fly ash (Rai *et al.* 2004; Sinha *et al*. 2005).

Crops grown together with prosopis *to enhance yields*

In silvopastoral systems where trees are grown together with grasses, the use of prosopis has resulted in a significant increase in nutrient cycling and biological production. It has been found that the incorporation of litter and root residues from prosopis into the soil significantly enhances the formation of soil organic matter and the increase in nutrient levels (Kaur *et al.* 2002a). In another trial on sodic soils, where trees were grown together with grasses, the establishment of prosopis with the grass *Leptochloa fusca* (L.) Kunth, favourably influenced the physic-chemical and biological properties of the soil. There was also an increase in carbon storage in plant biomass and a higher input of organic matter into the soil; this suggests a viable land-use option capable of improving the fertility of highly sodic soils (Kaur *et al.* 2002b).

Trees that are not only used for timber production but also for non-timber forest products (NTFPs) are referred to as multi-purpose tree species (MPTS) and are widely used in agroforestry. Their potential for soil improvement, which takes place through a better soil moisture regime, activation of micro-organisms in the soil, and a better and more efficient cycling of nutrients, is recognised and appreciated. *P. juliflora* and *P. cineraria* (*khejri*, which is indigenous to India), have been used to test their ability to ameliorate soil fertility. The yield of pearl millet grown under stands of *P. juliflora* and *P. cineraria* has been two to three times higher compared to open field conditions. In comparison to growth in an open field, the efficiency of applied nitrogen increased from 27 percent to 46 percent beneath the canopy of *P. cineraria* (Aggarwal 1998).

The productivity in chickpea (*Cicer arietinum* L.), when grown together with *P. cineraria*, has shown encouraging results. Plant density, total biomass and grain yield were higher under the canopy of *P. cineraria* up to a distance of 14 m, beyond which no effect of the tree on crop productivity was measured. This traditional form of agroforestry is practiced among the Bishnois, for whom *P. cineraria* is a sacred tree, in Rajasthan and Haryana. The positive influence on crop growth is associated with the improvement of soil properties under tree canopies of *P. cineraria* when compared to the open field. The moisture content under the trees was found to be higher at all soil depths, which was suggested to be the reason behind improved soil conditions (Puri *et al*. 1994).

2.1.5. Management and utilisation of *Prosopis*

In areas where prosopis has spread intensely, the woody plant usually reaches the size of a shrub when growing in dense thickets. However, there are several methods, tested in the field, that enable the woody plant to grow to the size of a tree so that it has many applications in the wood-processing industry. Pruning enhances the growth of prosopis, creating large, straight, and single-trunk trees with increased diameter and height. Pruning increases the stem diameter due to improved photosynthesis and the allocation of its products within the tree. Prosopis responds positively to pruning with a rapid increase of new leaf growth. Although the leaf biomass is reduced immediately after pruning, there is an increase of above-ground growth after four months (ElFadl and Luukkanen 2003).

After pruning, prosopis shows an increase in photosynthesis rates on leaf area unit compared to untreated trees. The reduced leaf area causes a reduction in the total transpiration rate, thus increasing the leaf water potential and leaf turgor and leading to greater leaf CO_2 conductance. The trees use the increased flow of photosynthates for growth and metabolic processes, with the effect of an increase of diameter growth to twice the rate found in unpruned trees. The height increases with more intensive pruning until a specific limit, beyond which a reduction is noted. It has been suggested that this is due to a decrease in light competition, since at a certain level of light intensity the tree crowns become flattened and the trees tend to invest in lateral growth of the lower remaining branches (ElFadl 1997). Pruning has proved to be most effective when branches are removed up to three quarters of the total tree height, leaving only the top quarter with branches and foliage. In this way the tree grows a singular thick stem with a green leaf mass sufficient to provide the material and energy for growth (ElFadl and Luukkanen 2003).

The challenge of silvicultural management of prosopis is thus to transform dense stands into fewer large trees with wider spacing. Newly formed prosopis stands (10 -15 years of age) with a high number of small stems (1-2 cm in diameter) are most problematic because of their impenetrable nature and the high risk of injuries when cutting for fuelwood. These dense thickets do not allow any grass production on pasture land.

An investigation of self-thinning regimes in *Prosopis glandulosa* var. *glandulosa* Torr. revealed a negative logarithmic regression of stem density in relation to tree size. The results suggest that the mechanical thinning of tree stands should be done according to the desired tree size. Felker *et al.* (1990) predicted a maximum timber volume (22 m^3 ha^{-1}) with 42 cm diameter stem size at a spacing of 9.5 m. This would result in a population of 111 stems ha^{-1} at the end of a rotation of 30 years. The study suggests that each successive thinning should not exceed 33 percent of the stem density. Felker and Patch (1996) found that after the initial reduction of stem density to about 100 pruned trees/ha, there would be a need to apply additional pruning after 3, 8, and 13 years. The biomass released from pruning and thinning provides fuelwood and dry-fencing material.

Eventually, after the desired optimal number of trees per hectare is obtained, large trees provide sufficient intraspecific competition that prevents small seedlings from becoming established. Both thinning and pruning may require the application of herbicides to reduce stump and stem resprouting. If *P. glandulosa* var. *glandulosa* is cut off at the ground level, coppicing appears from several basal sprouts and suckers, due to an extensive pre-existing root system. Coppice sprouts usually grow much faster than seedlings. A solution of 20 percent triclopyr mixed with diesel oil or vegetable oil showed the most promising results in reducing resprouting. The solution can be applied with the use of paint brushes. Higher concentrations of triclopyr in diesel oil applied to the pruned site caused a reduction in growth and even tree mortality (Patch *et al.* 1998). The rather newly developed herbicide, clopyralid, is even more effective when killing of trees of the species *P. glandulosa* var. *glandulosa* is needed (Cornejo-Oviedo *et al.* 1991). Although clopyralid has been shown to be more risky in causing mortality in *P. glandulosa* var. *glandulosa*, it was not more effective in suppressing resprouting. In addition, clopyralid is a restricted chemical and does not offer any price advantage to triclopyr, which makes the use of triclopyr a better option (Patch *et al.* 1998).

A pacing of approximately 100 trees/ha would make grazing in shade conditions under tree canopies possible, thus reducing farmers' additional costs for livestock fodder. Grasses can be utilized also in a cut-and-carry system. Certain valuable perennial grass species have been found growing beneath mature stands of *Prosopis* species. The establishment of the warm-season grasses green panic (*Panicum maximum* var. *trichoglume* Robyns) and plains bristle grass (*Setaria*

leucopila (Scribn. & Merr.) K. Schum.) beneath the canopy of mature *Prosopis* stands (*Prosopis glandulosa* var. *glandulosa*) indicated a significant increase in grass dry matter production under tree canopies compared to open spaces. Although an increase in dry matter was observed only at the first of four harvests, both grasses exhibited a trend for better production under the canopies (East and Felker 1993). The reason for enhanced grass production under thinned *Prosopis* spp. stands is explained by the strong influence of the trees on net radiation and soil temperature (Tiedemann and Klemmedson 1977). Increases in the moisture content and levels of organic carbon (C) and nitrogen (N) under *Prosopis* spp. canopies obviously also contributed to enhanced grass production (East and Felker 1993).

Genetic improvement of Prosopis

The genus *Prosopis* possesses many outstanding qualities like a high net photosynthetic rate, the ability to fix atmospheric nitrogen, an ability to grow in harsh climatic conditions, and the ability to survive with seawater supply and at soil pH above 9. Although all those useful characteristics are present in various *Prosopis* species, they do not normally exist within the same genotype. This problem is further complicated by the fact that it has not always been clearly identified which species occur in the new exotic environments. However, the species that survived in new areas were most likely the ones that possessed defence mechanisms ensuring their survival and adaptation. It has been suggested that strong and long thorns and multiple stems are strategies which the *Prosopis* species developed against selection pressure caused by animals or fuelwood harvesting (Felker 2009).

The species *P. alba* is mentioned as an example to support this hypothesis. *P. alba* usually does not survive outside its indigenous range in Argentina because of its tiny thorns and its highly palatable foliage that is browsed on by livestock. *P. juliflora*, on the other hand, has large spines and its leaves are seldom eaten by animals; it is also the most invasive *Prosopis* species in tropical countries outside its native range.

The scientific community has started to put more emphasis on the application of traditional forest genetic improvement to *P. juliflora*. It is known that most introductions of prosopis have usually originated from a narrow genetic base. After the species has become naturalised, the genetic base has further narrowed. This has produced trees that are thorny, shrubby in habit and form, and aggressively invasive. Breeding for new genetically altered types should aim at replacing the existing prosopis populations with new ones with very small or even non-existent thorns, palatable pods that could be used for human food, and a single-stemmed erect growth form. There are various methods available that could be used in further domestication of prosopis.

A promising technique used in clonal propagation is grafting (Tewari *et al.* 2000). Clones produced in this way could be used to suppress the existing non-productive or undesired naturalised stands and transform them into stands that contain as many of the favourable qualities as possible. Grafting could also yield a combination of a rootstock that is resistant to salinity with a scion that is taken from a genotype that is fast growing and produces a high yield of palatable pods (Alban *et al.* 2002).

The technique of rooted cuttings has shown only little success in prosopis and a low survival rate compared to grafted plants. It is far easier to propagate prosopis from seed than using clonal propagation. Since prosopis is self-incompatible, a mechanism that prevents self-fertilization and encourages outcrossing, it is easy to introduce new genetic material into the breeding line and

quickly increase the genetic diversity. New genotypes, consisting of hybrids between the various clones, can be grown in orchards. The seeds can then be collected and transferred into the desired plantations after removing the existing trees on the new planting site. A mature tree is able to produce 40 kg of pods which means that a seed orchard of one hectare is capable of producing 6 million seeds annually (Alban *et al.* 2002).

Rapid grafting of scions from 30-day-old seedlings onto stems 1.5 mm in diameter has proved to be a feasible option to create clonal agroforestry plantations on a commercial scale. In Argentina, *P. alba* has proved to be the optimal species to be used in commercial scale plantations from rooted cuttings as it appears to be the easiest *Prosopis* species to root. Grafting *P. alba* onto *P. ruscifolia* is assumed to offer an effective weed control against the invasion of *P. ruscifolia* in Argentina. However, although *P. alba* could be easily grafted onto one-year-old rootstock grown in the nursery, there is no experience to indicate how the same approach will succeed when grafting *P. alba* onto mature trees in the field (Ewens and Felker 2003).

Good results have been obtained by grafting *P. juliflora* with spineless or less spiny species, producing straight boles and high pod yielding individuals of *P. alba* and *P. pallida*. Grafted scions have shown rapid growth; August or September has been the most suitable time to perform the operations, as shown at CAZRI (Central Arid Zone Research Institute) in Jodhpur, India (Tewari *et al.* 2000). Trials in Haiti also confirmed significant graft compatibility between the South American species *P. alba* or *P. chilensis* and the local *P. juliflora* (Wojtusik *et al.* 1993).

In India, an experiment was undertaken to evaluate the performance of non-thorny grafts from Peruvian *Prosopis* species that were grafted on the local thorny *P. juliflora*. The new trees consisted of one-year-old field-transplanted saplings and five-month-old nursery seedlings. The success rate was 70 percent for both trials. In another experiment, *P. chilensis*, *P. alba*, or *P. nigra* was grafted onto local *P. juliflora* with a success rate of 50 percent (Harsh and Tewari 1998).

The domestication of *P. alba* in a long term genetic improvement process has resulted in a new distinct variety of this South American *Prosopis* species that contains a number of desirable features. The new type is thornless and produces yellow pods that contain 30 percent sugar and can be used as livestock feed. The variety was patented in the US in 1995 under the cultivar name ‘Laurie’. It shows slower vertical growth with a greater girth to height ratio. It also exhibits complete resistance to cotton root rot, *Phymatotrichum omnivorum* (Duggar) Hennebert. (US Patent 1995).

Prosopis as livestock feed

Almost half of the earth’s land surface is used for grazing and the production of forage, which makes it the largest form of land use in the world. In arid and semi-arid areas, trees and shrubs supply the major feed for livestock. Livestock production in those areas is often the most economically viable, and often the only, way to utilize the vast lands that are characterized by scarce water resources and recurring droughts. The value of *Prosopis* species in general, and *P. juliflora* in particular, lies in the fact that they are able to survive and grow in the most harsh dryland conditions where other plants would not survive (Ibrahim 1988).

The use of prosopis pods as a livestock feed is of great advantage in the arid and semi-arid areas of India. Prosopis grows naturally in drought affected areas, requiring only small quantities of water for its growth. Malnutrition is one of the multiple hazards that livestock faces under these harsh

conditions. It has been observed that a mature 10-year-old tree grown under good conditions of soil and water availability is able to produce 90 kg of pods per year (Rawat *et al*. 1992). A pod yield of 2,000 kg/ ha of prosopis was estimated for the unmanaged Arizona dessert in North America and 4,000-20,000 kg/ha in the arid Hawaiian savannas (Felker and Bandurski 1979). In the north-east of Brazil, pod yields of 2-3 tons/ha are produced even on shallow stony soils with vegetation typical of semi-arid regions and with no agricultural value. Pod production of prosopis can be increased three to four times if irrigation is provided during the flowering period, which lasts two months. However, pod production may continue even after a drought period of 2-3 years (Riveros 1992).

Prosopis pods contain 20-30 percent sucrose and about 15 percent crude protein (Del Valle *et al.* 1983). They can be used in various ways as animal feed without causing any adverse digestive effects when used properly. Although crushed and ground pods are suggested as an additional feed, the feasibility of these techniques is questioned due to limited availability of manpower that processes the pods, causing additional expenditure to the average livestock farmer. It is further suggested that the pods should be mixed with other feed and that continued feeding of pods to cattle as the only diet should be avoided (Rawat *et al*. 1992). Pods in well-preserved silage have produced excellent livestock feed. However, the cost and availability of those additives make their use difficult. The ensiling of prosopis pods together with dry grass, like the dessert sewan grass *Lasiurus sindicus* Henr., is able to improve the nutritional value of the feed without pre-treatment (Pancholy and Mali 1999).

The inclusion of prosopis pods in the diet of Indian sheep, under a feedlot system growing lambs for meat production, indicated that the incorporation of 15 to 30 percent pods into the feed significantly lowered the feeding costs. A diet consisting of 15 percent pods added to other ingredients, like wheat straw (30 percent), alpha alpha hay (20 percent) and other minor components like wheat bran, urea, mineral mixture and salt (3.5 percent), showed superior feed efficiency (Ravikala *et al.* 1995). In whatever way the pods are used, crushed and ground or otherwise prepared as a mixture, whenever the seeds are destroyed in the process it has an influence on the control of the prosopis invasion.

The use of prosopis pods as livestock feed provides the farmer monetary savings. It is a low cost solution compared with other commercial animal feeds. The pods have a high concentration of proteins and the tree easily adapts to semi-arid conditions where hardly anything else is able to grow. Other products like honey and beewax provide additional income to the families in these areas and thus contribute to diversifying their livelihood opportunities.

Very few animals graze on the foliage of *P. juliflora* because of its unpalatable leaves and long spines. The leaves of *P. cineraria,* on the other hand, are browsed on by various animals. *P. cineraria* (*khejri*), which is native to India, is a slow-growing tree that develops a height of 6 m only after 10-15 years, compared to a height of 12-15 m in 4-5 years in *P. juliflora*. *Khejri* is well adapted to low rainfall (150-500 mm annually) areas. The particular feature of the tree is that it produces its leaves, flowers and pods during the hottest period of the year, between March and June. Thus the tree offers great opportunities as a forage resource in the extremely arid zones during the hottest season. Although *khejri* produces animal feed only after 10 years, under proper management regimes it continues production for up to two decades. Annually, the tree produces an average of 25-30 kg of dry leaf forage (Riveros 1992).

The pods of *khejri* are green and commonly known as *sangri*. *Sangri* is used in Indian cooking for human consumption as a vegetable. The pods are used in the immature or ripe form to prepare vegetables, pickles and various other dishes. Dried pods are used by rural people on a daily basis.

Khejri possesses an important role as drought food in the arid zones where vegetable growing is a difficult undertaking (Tewari 1998).

Like *P. juliflora, khejri* also contributes to higher yields of crops like pearl millet, cowpea, guar bean, buffel grass and others when grown in the interspaces of the trees (Kaushik and Kumar 2003). *Khejri* is indigenous to India and in many regions even protected as a sacred tree (Gold and Gujar 2002; Gadgil and Guha 1992). However, due to its ecological competitive advantages compared to *P. cineraria* and the capacity to alter the ecosystems of the regions it invades, *P. juliflora* continuesly diminishes the space of the indigenous *khejri* tree. It has been concluded that the higher demand for nutriens of *P. juliflora* also causes disturbance of the soil profile, consequently depleting it of nutrient, which gives the exotic invader advantages over *khejri* (Sharma and Dakshini 1991).

Prosopis as a honey tree

Prosopis regularly produces an abundant amount of flowers that are used for forage by honeybees even during times of drought. After the introduction of prosopis into Hawaii in the 1930s, the island became one of the largest producers of honey.

The honey produced from prosopis flowers is claimed to be of excellent quality. A substantial amount of this honey (300 metric tons) was harvested and marketed during a five year period in the early 1990s in the state of Gujarat alone. The rare local honeybee species *Apis florea* (Fabricius) and *A. cerana* (Fabricius) use the nectar and pollen of prosopis to produce honey which is also used in traditional medicine (Varshney 1996; Pasiecznik *et al.* 2001).

A large number of beekeepers in South India earn their living from *Apis cerana* bees, which are known to be good pollinators. *Apis florea* (dwarf honeybee) has adjusted to the extreme climate of the arid and semi-arid zones and occurs in large numbers in the arid zones of Gujarat; it is also present in smaller numbers in South India (Thomas *et al.* 2002). Beeswax is used as a pharmaceutical and industrial raw material, out of which candles, creams and balms are manufactured (Varshney 1996).

2.1.6. *Prosopis* invasions and control

In numerous tropical arid and semi-arid regions, the genus *Prosopis* has invaded large areas wherever optimal conditions for its spread are available. The adaptive ecological traits of the *Prosopis* species, especially their competitiveness against indigenous plant species, have led to an invasion in some areas that creates hazards for people and the environment.

In India, the initial distribution of prosopis was observed in regions with 150-750 mm of mean annual rainfall. However, the wide ecological amplitude of the tree has enabled it to spread into large rice growing stretches of the Cauvery River Delta in Tamil Nadu, an area with a mean annual rainfall of 1,500 mm, where annual floods are common. The present occurrence of prosopis reaches from the state of Punjab in the north to Tamil Nadu in the south, from Gujarat in the west to Orissa in the east, with naturalized stands found at altitudes up to 1,200 m above sea level. The original planted area in the state of Gujarat of 31,550 hectares has expanded six times, to 200,000 hectares now invaded by prosopis. It is estimated that the overall coverage of prosopis in India exceeds

approximately 5.55 million hectares, that is, 1.8 percent of the whole geographical area (Kathiresan 2006).

Traditionally in Gujarat, a few million pastoralists have used common lands and agricultural fields after the harvest as the main sources of food for their grazing herds. In 1965 the report of the Gopalak Samiti recognized for the first time in the state, the existence of the Â‘Maldhari Â‘ pastoralists and their diverse and rich grasslands. Among various suggestions of the committee to improve the grasslands and pastoral livelihoods, there was also a caution about the likely dangers of afforestation programs.

However, to control salinity in the area, plantations of prosopis were established in many of the natural grasslands. Prosopis, which is locally known as *gando baaval*, has gradually invaded these grasslands, thereby replacing indigenous grasses and other types of vegetation. Today, the significant resource of huge natural grasslands in the semi-arid region of Gujarat has been destroyed. Besides the invasion, salinity has increased due to the building of roads for facilitating army activities during the 1965 war with Pakistan. In this process the eastwards flow of sea water was obstructed, which caused salt water to flow into the grasslands. Pastoralists have lost their grazing grounds, forcing them to move out of their previous rangelands, with many of them settling on the outskirts of urban centres where they need to purchase fodder for their diminished herds (Bharwada and Mahajan 2006).

In Rajasthan, the arid and semi-arid areas have been depleted of tree coverage due to massive deforestation. As a result, prosopis has become the most important source for fuelwood for the local people. Although people appreciate the fuelwood supply from the tree they call "*vilayati bambul*" (foreign tree), they complain about several negative effects caused by the tree. The favourable perceptions of the local people about prosopis during the initial stages of the introduction changed to criticism after the negative aspects of the tree became obvious. Similar to reports from many other tropical drylands with prosopis infestations, the colonization of the tree into agricultural lands has become a significant threat to the farmers' economy. There are also reported occurrences of serious infections to humans and livestock, caused by the thorns. People have become aware that the benefits they receive from prosopis are fewer compared with native trees and they associate "*vilayati bambul*" with a downgraded quality of life (Binggeli 2001).

In Ethiopia, prosopis is an aggressive invader of the pastoral lands of the Middle and Upper Awash Valley that causes serious problems for the pastoralists in the region. The tree causes substantial difficulties for the farmers who cultivate irrigated land because of the invasion into the crop fields and the problems it causes to the irrigation system. In the most infested areas it affects the composition and structure of the indigenous species. Prosopis is classified as one of the three most problematic invasive species in the country, together with *Parthenium hysterophorus* L., an agricultural weed, and the Water hyacinth, *Eichhornia crassipes* (Mart.) Solms (Teketay and Bekele 2002).

Essa *et al.* (2006) did a study to evaluate the dynamics of prosopis in the United Arab Emirates (UAE), using high resolution digital aerial photographs. The study revealed that prosopis had become a real threat to local native species because of the increased invasion. The arid areas of the Northern Emirates had a mean annual precipitation of 158 mm during the period from 1986 to 2005. Results show a rapid increase of its cover during the 19-year period. Also patch density[7] of prosopis increased significantly, especially during the first ten years of observation, with 18.4

7 A patch represents an area, which is covered by one single land cover class (area/ha).

percent above average annual rainfall (174 mm). In the Khut area, one of the two selected study sites, there was no prosopis earlier because of farming activities. However, after agriculture was abandoned, the prosopis canopy cover increased from 1.1 to 13.1 percent during the two decades of observation, an average of 1.2 percentage units per year (Essa *et al.* 2006).

The dynamics of the prosopis invasion showed similar features in both the Khut (16 ha) and Filayah (94 ha) areas. During the first 10 years, from 1985 to 1995, there was an enhanced increase in canopy cover and patch density which was attributed to higher rainfall occurrence. During the second period, from 1996 to 2005, average annual rainfall decreased by 4.1 percent, which was followed by a decrease of both expansion of canopy cover and patch density. During the dryer period, prosopis recruited new small patches because of its reported adaptive advantages over other species during harsh weather conditions. It was also observed that at the end of the second period, both sites reached saturation, with prosopis stands reaching climax conditions (Essa *et al.* 2006).

From many places in the tropical world where prosopis invasions have caused damage to the environment and to people's livelihood, there are reported experiences of success in controlling such invasions. However, complete eradication of prosopis has proved to be a difficult and expensive undertaking. Although there are reports of successful interventions in smaller areas invaded by the species, it has shown to be extremely difficult, even impossible, to eradicate it over a wide terrain. One of the important requirements necessary to succeed in eradication is the control of the movement of animals in order to hinder new infestations.

In India, a successful example of prosopis eradication in a sensitive natural habitat has been reported from the State of Rajasthan. An area of almost 3,000 ha of wetlands surrounded by grassland and shrub forest was upgraded to the status of a national park because of its high level of biodiversity. As a consequence, people were prohibited from cutting wood and grazing their livestock in the park, which caused frictions between local communities and the Forest Department. Since 1985, the park known as the Keoladeo National Park, has become a nature landmark and it is listed as a World Heritage Site. An almost complete failure of the monsoon rains during 2006 and 2007 resulted in a massive invasion of the park by prosopis, which invaded both the wetlands and grasslands. The dense stands of the tree hindered birds and other wildlife from returning to their habitats. Indigenous vegetation was to a high degree made extinct and replaced by the alien invader. To rehabilitate the park to allow the return of the migratory birds, among them the rare Siberian Crane (*Grus leucogeranus* Pallas), the committee of the park has encouraged local people to participate in a campaign to eradicate prosopis. They were allowed to keep the wood as fuelwood or use it as fence poles. The report, listed by the World Heritage Committee, mentioned that there was an active participation among the villagers and the eradication campaign is believed to have reached its target (World Heritage 2008).

Trials from India found that slashing and digging out the roots were the most effective method to eradicate prosopis; it controlled regeneration for up to 12 months (Kathiresan 2006). Additionally, chemicals were applied after cutting. Tordon (Picloram and 2, 4-D), used in strong doses, was able to hinder stumps from resprouting. In Sudan, the use of the herbicides triclopyr and clopyralid, sprayed on the foliage of prosopis trees or mixed with diesel and applied to the stem base, showed encouraging results (Babiker 2006). In Yemen, where prosopis causes distress to farmers because of its invasion into croplands, ploughing the infested area in combination with the control of new shoots effectively reduced the plant in some territories (Al-Shurai and Labrada 2006). In Australia, trials of aerial spray treatments, applied by helicopters, revealed a mortality rate of more than 90 percent. The chemical used was Grazon DS (4 l/ha) mixed in 200 litres of water with an added

wetting agent (BS 1000). The costs were 250-280 Australian $/ha which would be extremely costly, for example, in India. Aerial application can also kill native plants and pastures (Csurhes 1996).

2.2. Sacred native plants of India

India has a considerable amount of tree species that are regarded as sacred. Hindus believe that trees and plants are conscious beings with the capability of experiencing pleasure and pain (Bühler 1886). In general, the most deified trees are indigenous species. It is believed that particular deities always occupy the same kind of tree species as their abode. However, demons are also believed to seek shelter in trees since they also require protection from bad weather conditions, as do humans. Serpent worship is connected to tree worship due to the fact that serpents are often found at the roots of trees. Since demons are believed to occupy both snakes and trees, and *Śiva* is known as the Lord of demons, serpents and plants, there is a close connection between tree, serpent, demon, and *Śiva* worship (Monier-Williams 1883).

The bodhi tree

The bodhi, or peepul (Sanskrit: *pipal*) tree (*Ficus religiosa* L.), also called the arali or *aśvattha* tree, is regarded as one of the most sacred trees for Hindus and Buddhists. It is said that Prince Siddhartha reached enlightenment while meditating under a bodhi tree. After this happening he became known as the Buddha and the tree was henceforth called the sacred fig; its leaf also became a symbol widely used in Buddhism (Cowen 1984). For Hindus, the bodhi tree is associated with the Hindu gods *Brahmā, Viṣṇu,* and *Śiva*. *Viṣṇu* is said to have been born under a bodhi tree and thus is considered to be the tree. Often bodhi trees are married with neem or banana trees. It is strictly prohibited for any devotee to fell, harm of utilize the tree (Cowen 1984).

Because the bodhi tree is an esteemed symbol of worship, it is not used for any economic purpose. People might use its leaves or small branches for the preparation of medicines, as described in the teachings of the *ayurvedic* medical system. However, the resource is used in a prudent way so as not to harm the tree. The bodhi tree is considered the tree of the Brahmins, who offer their prayers while facing towards the east. Frequently the bodhi tree is decorated with cloth like silk shawls and in Gujarat devotees place the sacred triple cord of the Brahmins on its trunk or twigs. In Bengal, *Manasa*, the goddess of serpents is believed to reside in the tree (Gandhi and Singh 1994).

The banyan tree

Another Ficus species, the banyan tree (*Ficus indica* L. or *F. benghalensis* L.), *vaṭa*, or *nyadgrodha* in Sanskrit and bor, bar, ber, bargat in Hindi, looks similar to the bodhi tree except for the leaf shape. The physical appearance of both the bodhi and the banyan tree is one of the aspects that make people adore them. Besides their height, it is the beauty, massiveness of the trunk, and the old age both bodhi and banyan trees are able to reach, that fascinate people. Under their wide-spreading branches humans and animals are able to seek shade and protection. The banyan tree has an exceptional way of growth, sending down aerial roots from its wide-spread horizontal branches that later become new trunks. It has been reported that a cluster of such a tree, including its central trunk and the upright roots, may cover a ground area of 1,500-2,000 feet in circumference (Simoons

1998). It is described as a marvel of nature and is admired as a shining example of the beauty of all vegetation (Ragozin 1902).

A banyan tree near Madras (today Chennai) has been measured to have a diameter of twenty-eight feet, being surrounded by twenty-seven trunks (each about eleven feet in diameter), established from air roots in the first generation. Each trunk, once steadily rooted, has the capability to develop horizontal branches which again drop root-vines into the ground. This process is ongoing whenever new soil is available to provide nourishment for further growth (Ragozin 1902).

Together with the River Ganges and the Himalayas, the banyan tree is often used to depict the image of India. The tree is seen as a symbol of fertility and is worshipped by those longing for children. The three gods of the Hindu triad are associated with the banyan tree: *Viṣṇu* is embodied in the bark, *Brahmā* in the roots and *Śiva* in the branches. The deity *Lakṣmī* is said to visit the tree on Sundays. It is believed among Hindus that a pilgrimage to one of the appointed famous banyan trees will substitute for twelve years of sacrifice. A person who rubs the ashes of any part of the tree onto the skin will be freed from all sins (Gandhi and Singh 1994).

The neem tree

The neem tree (*Azadirachta indica* A. Juss.) is often found along the roadsides all over India. It is able to withstand dry periods and is used for house building, furniture, or agricultural tools. In South India it is also called the "life giving tree". Neem is classified as a divine tree and locals regard it as the village pharmacy. All parts of the neem tree are particularly used in *ayurvedic* medicine. The essence extracted from the yellow fruit is used for various ailments and is known as *Margosa* oil. The oil is used for the treatment of leprosy and various skin diseases. Oil from the seeds contains antiseptic properties and it is believed to cure rheumatism (Cowen 1984, Shiva 1989).

The neem tree is inhabited by the deity *Sītalā* and her sisters who are worshipped as the goddesses of disease. In the past, during epidemic periods, mostly in hot monsoon seasons, women prepared and dressed themselves festively and placed their offerings of rice, sandalwood and flowers on the roots of a particular neem tree (Crooke 1896). The neem tree and the goddess residing in it are especially worshipped by women and neem leaves are placed on the door of the house to gain protection when smallpox occurs in a village. Generally, the neem tree is believed to have the ability to cure, purify and protect from evil (Simoons 1998).

The bel tree

The bel tree (*Aegle marmelos* (L.) Corrêa ex Roxb.) is a deciduous tree with strong spines and trifoliate leaves. Although the wood is of excellent quality and could be used for many purposes, it is not utilized because the entire tree is supposed to be sacred. The only use is in sacrificial rites. Its leaves are offered to Lord *Śiva* (Sinha 1979). In the Puranas, bel is associated with the goddess *Lakṣmī* but in different regional and tribal communities it is related to many other Hindu deities. The wood is used for the oblation in Hindu marriage and in funeral pyres for the burning of the dead bodies of wealthy Hindus (Gupta 1980). It is also called the "woodapple" due to its nutritious fruits. The leaf is shaped in triple form, with three leaflets which resemble the three headed spear of *Śiva.* The leaves are placed on the *liṅgam* (phallus symbol) or on Nandi, the bull, which is said to be the vehicle of Lord *Śiva* (Monier-Williams 1883).

The mohwa tree

The mohwa tree (*Madhuca longifolia* J.F. Macbr.) is of particular importance for the tribe of Chattisgarh, living in the mountain areas of Bastar and the Satpuras. It is known as the "Indian Butter Tree" and it is regarded as one of the most important trees in India. Forest dwellers in Central India call the mohwa the tree of life. The fleshy corollas are collected by women and converted into various food items that are eaten raw, cooked, dried or ground. The mohwa tree is found scattered also outside the forests on agricultural lands because the tree is always preserved, even when forest lands are converted into agricultural land (Shiva 1989).

The ashoka tree

The ashoka tree (*Saraca asoca* (Roxb.) De Wilde) is considered sacred throughout India and Sri Lanka. It is the tree under which the Buddha is believed to have been born in Lumbini in North India. In the epic, Rāmāyaṇa, Lord *Rāma's* wife *Sitā* is said to have taken refuge in an ashoka tree grove after escaping from *Rāvaṇa*, the king of Lanka. The tree is of economic and medical value (Sinha 1979). The pulp of the blossoms is used as a remedy for dysentery and the juices from boiled bark have the ability to heal some ailments of women (Cowen 1984). Hindus and Buddhists worship the tree on the thirteenth day of the Chaitra month, usually the 27th of April (Gandhi and Singh 1994).

Tulsi, the holy basil

Among the sacred plants of India, the tulsi plant occupies a significant place as the most worshipped herb in Hindu culture. Tulsi (*Ocimum sanctum* L.), or holy basil (Sanskrit: *tulasī*), is rather unknown in the Western world but is widespread in India. The woody herb or small shrub that grows to a size of one to two feet is cultivated or grows wild on the Indian subcontinent. The plant is commonly grown in homes and near temples. It contains various remedial qualities and is used as an antidote for snake bites. The stimulating juice of the leaves is used as a remedy to cure bronchitis and catarrh. Seeds are used to cure disorders of the genitor-urinary system (Sinha 1979). Tulsi is believed to eliminate blood toxins and strengthens the heart.

Hindus believe that *Brahmā*, the creator god, has his abode in the branches of the tulsi plant, other gods are present in its leaves, and the sacred Ganges is at its roots. The God *Viṣṇu* is worshipped in the tulsi plant which makes it a sectarian symbol of Vaishnavism (Simoons 1998). However, the plant is not merely sacred to *Viṣṇu* but also to his wife *Lakṣmī*. The plant itself is worshipped as a deity that receives prayers from its worshippers. The tulsi is found in almost every Hindu household, usually planted in the court-yard, and it was traditionally an object of worship for women (Monier-Williams 1883).

2.3. A brief overview of India's history, current policy and caste system

2.3.1. A brief history of India[8]

In order to provide the context for the region of focus, this short description of the history of India until independence is meant to help in understanding the vast diversity of different religions and cultural practices in contemporary India. It is far too exhausting to give a detailed historical background of the history of India as part of this thesis. However, even a short outline of some of the major historical events that leave their traces even today might help to contextualize attitudes towards the environment. India is an accumulation of different civilizations, traditions, and languages that live and act together under a central government. The nation consists of an extremely diverse geographical area that includes six major climatic zones, including tropical regions, deserts, tundra and the glaciers of the Himalayas in the north.

The Aryans

The pre-historic period of India begins with the Harappan Culture (ca. 2300 B.C.) which developed in the Indus Valley in the north-west, now Pakistan, and in the area of the contemporary states of Rajasthan and Gujarat. In the Vedic period, around the third millennium B.C., the region was a geographical entity that was divided into five regions that are similar to the modern regional division of the country. The presence of the Aryans, who migrated and settled in the area from central Asia, can be traced in the Vedic literature that mentions the important rivers in the region. It is believed that during this era, the establishment of villages and the caste system was introduced in *Āryāvarta*, the name of the area at that time. The area in the south of the country was occupied by non-Aryan tribes known as the Rakshasas and Asuras.

The Brahmanic and Buddhist Age

During the Brahmanic age (800 B.C. to A.D. 1000), which is also known for the rise of Buddhism, the Hindu civilization spread towards the south, establishing kingdoms like Anga, Andhra, Pandya and Vidha, to mention a few. The birth of Siddhārtha Gautama, later known as the Lord Buddha, in 577 B.C. (time of birth and death are uncertain) was followed by the spread of Buddhism in India and many other regions of Southeast Asia. Invaders from the west, like Darius (invaded Pujab in 500 B.C.) and Alexander the Great (defeated Porus in the battle of Jhelum in 326 B.C.), attacked India during this period. It was the time when the seeds of Buddhism were sown. Among the literature contributions are the Sutras, the laws of Manu, Sankhya by Kapila and The Yoga Philosophy of Patanjali.

The availability of agricultural land in the fertile lands of northern India enabled early chiefdoms to enlarge their territorities.The period from 500 B.C. to 300 A.D. was marked by the exploitation of natural resources. It encompassed the era of the Mauryan state that was keen in expanding agriculture and invading the area of Kalinga (contemporary Orissa State) under its emperer Ashoka. Ashoka, who was crowned as the King of Magadha (263 B.C.), conquered Kalinga in 256 B.C. and declared Buddhism as the state religion. Ashoka's Mauryan kingdom spread from the west of the

[8] The source material for this short historical introduction was mainly composed from Geography of India, by Nag and Sengupta (1992).

Indus to Bengal in the east. Ashoka converted to Buddhism and became known for his edicts that advaocated the moderate harvesting of plant and animal resources, including the demand for a ban on killing animals and orders for protecting trees. It was the time when the bodhi tree and forest life found its highest appreciation (Gadgil and Guha 1992).

The Muslim rule

The Rajput age marked the beginning of the Muslim rule in India. Other important events during this period were the birth of Nanak, the Guru and founder of the Sikh religion (1498), and the discovery of the sea route from Europe to India by the Portuguese explorer Vasco da Gama (1498), who reached Calicut in 1500 and Cochin in 1503. The arrival of the Europeans opened new trade and commerce activities which eventually lead to the colonisation of India by the British and other European countries.

The Muslim or Mughal rule started with Akbar the Great. His rule extended over large parts of India during 1556-1605. After his death, Jahangir, his son, became the next Mughal ruler. Jahangir died in 1627 and was succeeded by Shah Jahan (1627-1658), who became famous as the constructor of the Taj Mahal, which he built in memory of his wife and Queen Mumtaj Mahal. When he fell ill in 1657, his four sons started fighting for the throne. Aurungzeb finally succeeded and became the Moghul ruler from 1658-1707, during which time he expanded his kingdom to the Krishna River in the south.

The independent kingdom of Maratha, which was founded by the local king Shivaji, resisted various attacks by the Mughal armies. Finally, in 1707, after 27 years of various unsuccessful attacks, the Mughal rulers took over Maratha. With the declining power of the Moghul kings, territories in the east and south became independent. Marathas started to rule over the Deccan Plateau and the intervention of Nadir Shah of Persia in 1738 ended the period of the Mughal rule. The Maratha Empire, which covered large territories of south India, ended in 1818 with the Third Anglo-Maratha war (1817-1818) which left the British in control of most of India.

The British rule

The 18th century brought the first invaders from Europe to India. The French conquered Madras in 1746, Pondicherry in 1748, and took over the rule of the Deccan in 1750. During the same period the English East India Company became the ruler of Trichinopoly (today Tiruchirappalli), south of the river Cauveri. Until the end of the 18th century, the English invaders gradually expanded their power, taking over new terrain like Tanjore (today in Tamil Nadu), Surat (city and district in the contemporary state of Gujarat) and Carnatac (region between Tamil Nadu, south eastern Karnataka and Andhra Pradesh). The 19th century brought ever more and larger territorial annexations by the British, among them the Punjab (1844) and the Satara region in western India (1848).

The first war of independence between Indian freedom fighters and the army of the British East India Company took place in 1857 and ended with a British victory after the fall of Gwalior in 1858. Mohandas Karamchand Gandhi, an educated lawyer, who had returned from South Africa, took over the leadership of the Indian National Congress in 1885. He became the leading figure in the battle for independence, which India achieved in 1947. Later on, Gandhi was known as the father of the nation (Nag and Sengupta 1992).

2.3.2. The Indian caste system

Indian society is shaped by its caste system which is still a major force in the socio-economic and political life of the country. The caste system not only determines the traditional caste-based Hindu society but also most of the non-Hindus in India are descendents of former converts from Hinduism to Buddhism, Christianity, Islam or Sikhism. Although the structures and rigidness of the caste system is weakening in cities and urban areas, in rural villages it still influences profoundly the daily life of more than 600 million people.

Caste can be comprehended as a hierarchical division of the society into four large, ranked caste clusters called *varṇas* (literally: enclose or colour). Each *varṇa* has a traditional social function. At the top of the hierarchy are the *brahmins* (priests), followed by *kṣatriyas* (warriors), *vaiśyas* (peasants and merchants), and *śūdras* (service providers and artisans). Within the four main categories, there is a further segmentation of society into castes or *jātis* (birth). Chronologically, the *varṇas* emerged first as a theoretical system, laid out in the Hindu codes of the Dharmaśāstras. Later, on the micro level, thousands of caste groups or *jātis* evolved under the *varṇa* framework with particular importance for the local village societies. Each *jāti* refers to a strictly regulated group of people bound together by marriage and lineage, characterised by professional, religious, ritualistic and social roles. Thus caste can be described as a particular group of people characterised by endogamy, hereditary membership, and a specific style of life determined by the pursuit of a specific traditional occupation (Béteille 1965).

The castes have their origin in the Aryans settlements of the second millennium B.C. Traces of the Aryans are found in west Eurasia and it is a widely accepted theory that these pastoral nomads migrated into northwest India, expanding their power and influence into the Indo-Ganges plains (Bamshad *et al*. 2001). Over time they admixed with the indigenous Dravidic-speaking natives and created the caste system, placing themselves into the highest ranks. Dravidian natives, who were probably spread throughout the country before the arrival of the Aryans, retreated south to avoid dominance, or were forced to do so (Basu *et al*. 2003). Based on evidence, one can say that the fair skinned people penetrated into an area of dark-coloured natives and gradually ruled over increasing parts of the country. Thus the society became divided into hierarchical strata of social classes, first into the four *varṇas* and later into thousands of *jātis* within the clusters of the *varṇa* system (Tirtha 2002).

Although founded millenniums back, the functioning and principles of caste has basically remained the same until today. Humans are born into a caste and stay there during their whole life. The reason for a person's affiliation with a particular caste is explained as a function of *karma*, which either rewards good deeds done in previous lives with the shift into a higher caste or punishes bad actions with a drop into a lower caste. Good *karma* is done when leading a life according to the *dharma*, thus obeying religious and social obligations to one's caste. Each *jāti* is named and follows rules of endogamous marriage. Physical contact, associations and the consumption of food prepared by other castes are strictly avoided. Each caste has its particular ritual observances and solidarity within a *jāti* is kept through the traditional professions. There are distinct duties and obligations that are linked to status and ritual purity in order to serve the needs of the village community (Tirtha 2002). Within a *jāti*, the behaviour of its members and every major decision, be it marriage, occupation, place of residence, food or behaviour towards members from the same or different castes, is determined and regulated by kin (Quigley 1993).

The highest rank in the *varṇa* hierarchy is occupied by the Brahmans. The *jātis* within the *brahmanic varṇa* occupy positions and professions like priests, teachers, guardians of Hindu rituals

and governors of moral behaviour. Brahmanic priests are traditionally highly respected since they officiate in almost all the important rituals, from birth rituals to marriage performances to the final rites when a person departs this world. This prestigious position has enabled members of the highest caste to accumulate large segments of land that has been granted to them by local patrons and rulers. In local villages there are traditionally only a few Brahmin families, often making their living from agricultural land properties and the performances of the necessary Hindu rites in the community. They are usually better educated and receive services from members of lower castes (Tirtha 2002).

The caste ranking second highest in the *varṇa* system is the *kṣatriyas*, traditionally known as the warrior caste. While the traditional role of the *kṣatriyas* was to defend the society from outside invaders, they are today identified with land owning *jātis*. The *vaiśyas* rank below the *kṣatriyas* and members of their *jātis* are traditionally engaged in occupations associated with agriculture and trade. Today there are many successful business associations in India that belong to the trading caste of the *vaiśyas*. The lowest category of the *varṇa* system is occupied by the castes of the *śūdras*. They fall below the ritually high *varṇas* and are excluded from a number of ritual privileges. *Śūdras* form the majority of the rural population and they also represent the bulk of agricultural labourers. Other professions falling into this *varṇa* belong to artisan services like carpentry, metal work and pottery (Tirtha 2002).

Finally, at the bottom of the social stratification are the so-called casteless, also known as excluded or exterior castes. The upper castes called these people "untouchables" due to their "unclean" occupations like disposal of the dead, cleaning of latrines and menial work. Any physical contact with members of the untouchables was avoided by the higher castes. During the 1930s, the untouchables, which Gandhi addressed as *harijans*, "children of God", were given a new set of titles such as "Depressed Classes", "Exterior Castes" or "Scheduled Castes". The term "Scheduled Castes" was officially applied in the Government of India Act of 1935 for administrative and representative purposes. One year later, in 1936, the Government of India published a list of the Scheduled Castes. In addition, various tribal peoples, before regarded as casteless, were categorised under the common name "Scheduled Tribes" and both terms were widely adapted and used after independence in 1947 (Kunar 2002).

Traditionally each caste was associated with particular duties and obligations defined by ritual purity in order to serve the common needs of the village communities. The development of "*jajmani*"[9] relations enabled the hereditary patron of a community to receive services from hereditary artisans or servants for which he would pay in cash or agricultural goods. For instance, land owning castes exchanged grains and vegetables for services and products like ploughs or leather goods. Certain manual and menial jobs were forbidden or restricted to upper caste families due to their ritual position, which created the need for the *jajmani* system. Then, and still today, specific social and religious obligations of the various castes within the village are divided among the different *jātis*. Sweeping the floors, performing the rites of a marriage or producing various goods needed in daily life, all these services are carried out by a particular caste. Thus, interdependence developed that has preserved and strengthened the caste structure until the present day. Due to the rule of exogamy, a man is not supposed to select his wife from within his own ancestral lineage. Most common is the practise of creating marriage alliances with members of outside villages in a range of 4-12 miles. However, in South India marriage alliances are preferred between cross-cousins and nieces (Tirtha 2002).

[9] Relations between a food-producing family and the family that supply them with goods and services. A conflict-free, reciprocal and hierarchically weighted system of interrelated *varṇas* (Mandelbaum 1970).

The contemporary caste division in India follows largely the Indian census of 1931, where the "main" castes (excluding Scheduled Castes) were listed into 2378 *jātis*. After independence, the first national Backward Classes Commission was established in 1953 with the task to determine criteria of backwardness, using indicators such as social and economic position as well as education and occupation. Before it was unclear who belonged to these classes. In order to grant equality among all Indian citizens, laws were passed that forbid discrimination on the basis of caste, class or sex. The determination of socially and educationally Backward Classes was to enable the government to create policies of affirmative actions for appointments in government positions and education. Today, the government reserves 27 percent of positions in administration and higher education for members of the Backward Castes, which comprise about half of the population of India. Scheduled Castes and Scheduled Tribes, who make up 20 percent of India's citizens, are granted 15 percent of those positions (de Zwart 2000). The bulk of influential and high ranking positions in government and universities are occupied by the so-called Forward Classes. Forward Classes belong to *jātis* of the ritually higher *varṇas* like the *brahmins*, *kṣatriyas*, or *vaiśyas*. Individuals belonging to those *varṇas* are not qualified to receive any "Government of India Reservation" benefits.

In contemporary India the caste system has lost its rigidity in urban areas and members of all castes occupy positions in all strata of economic and political life. However, in the villages of rural India, where much of this data was collected, caste still plays a dominant role in daily life and each *jāti* performs its assigned role. The size of a village, its location and economic structure decides the number and size of different castes. However, the caste hierarchy is visible in residential segregation and the higher castes occupy houses of higher standard and built of better materials. Their residences are usually located in the centre of the village while members of the Scheduled Castes and Scheduled Tribes occupy areas on the edge of the villages. The dominant caste of a village is not the one with the majority in numbers of families, but the one that is most powerful in economic and political influence (Tirtha 2002).

2.3.3. Forest policy in contemporary India

Before the advent of the British rule in India the only commercial use of forests was the extraction of timber for the shipbuilding industry. Forests were principally used for non forest timber products (NFTPs) like spices, fruits or precious wood such as sandalwood. However, expansion of agricultural land use under the East Indian Company and the construction of the vast Indian railways after 1850 seriously depleted the timber resources of the country. The increase of the railway network from 32 km in 1853 to more than 50,000 km in 1910 required an enormous amount of timber (900 sleepers or 126 trees for two km of track), particularly sal (*Shorea robusta* C.F.Gaertn.), deodar cedar (*Cedrus deodara* (Roxb. ex D. Don) G. Don), and teak (*Tectona grandis* L. f.). In addition, the over-exploitation of forests had detrimental effects on the ecosystem: drying out of the land surface, soil degradation, flooding and silting up of rivers. As a consequence, the British administration established the first Forestry Service in 1854. Two years later the German botanist and forester, Dr. Dietrich Brandis, was appointed the head of the newly founded forestry department. He introduced so-called scientific forestry practices based on the principle of sustained yield. The objective was to produce timber without compromising the future productivity of the forests (Gadgil 1984; Oosthoek 2007).

The first forest policy adapted by the Government of India in 1894 reinforced the exclusive right of the state to the production, management, protection and control over forests. The policy of state

owned forests for the production of timber and revenue generation continued in the post-colonial period. The first forest policy of independent India was declared in 1952. The main focus was placed on the conversion of "low" value mixed forests into "high" value cultivation of commercial species, such as teak and eucalyptus. Thus, diverse forest ecosystems were converted into single species monocultures. The subsistence needs and participation of rural people was neglected. The second post-independence declaration, in 1976, still emphasised commercial forestry but located more funds for social and farm forestry on non-forest and private lands (all forests were owned by the state) (Saxena 1997).

Current National Forestry Policy 1988

The current forestry policy of India, known as the Forest Conservation Act, was introduced in 1988. In the preamble the forestry situation at the end of 1990 is described as:

> *"…over the years, forests in the country have suffered serious depletion. This is attributable to relentless pressures arising from ever-increasing demand for fuelwood, fodder and timber; inadequacy of protection measures; diversion of forest lands to non-forest uses without ensuring compensatory afforestation and essential environmental safeguards; and the tendency to look upon forests as revenue earning resource. The end to review the situation and to evolve, for the future, a new strategy of forest conservation has become imperative. Conservation includes preservation, maintenance, sustainable utilization, restoration, and enhancement of the natural environment. It has thus become necessary to review and revise the National Forest Policy"* (National Forest Policy 1988, 1).

The objectives of the new forestry policy have changed from timber production and revenue generation to conservation, protection and rehabilitation of forests. The new policy states clearly that forests are not to be commercially exploited for industry. It also stresses the importance of conserving soils and the environment and meeting the subsistence needs of rural and tribal people (Saxena 1997). The basic objectives of the current National Forestry Policy are the maintenance of ecological and environmental stability through preservation and, where required, restoration of the ecological balance. The serious depletion of forests is recognised as the main cause for severe environmental disturbances. The policy further aims at preserving the remaining natural forests with their significant biological diversity and genetic resources. Emphasis is also given to the subsistence needs of the rural and tribal populations. The new forest law aims to meet the requirements of those people for fuelwood, fodder, minor forest produce and small timber (National Forest Policy 1988).

Although most of the forests (97 percent) are owned by the government, it is now recognised that in order to provide the goods and services expected from the forests and to assure the livelihood of those people who are dependent on forests in a sustainable way, the communities should participate. Thus the new forest policy involves local communities in the protection and management of the forests through a Joint Forest Management (JFM) programme, issued in 1990 by the Indian government. This makes local communities important stakeholders in India's forests. The subsistence requirements of approximately 15 percent of the rural population that resides in close proximity to forests are derived from those forests. In return for the engagement of village communities in the protection and regeneration of degraded forests, they receive usufruct rights in forest produce (including NTFPs, grass, and firewood), become shareholders in the harvest income, and obtain a role in the management procedures of those forests (Saigal *et al.* 2002).

In essence, the JFM policy aims at creating a partnership between local users and the State Forest Department, sharing management tasks and responsibilities as well as benefits (Liu 2005). An overview of the impact of JFM reveals that by March 2006, a total of 106,482 JFM committees were managing 22 million ha of forests in 28 states and the Union Territory of Andaman & Nicobar Islands. This comprises almost 28 percent of the total forest area (Pai and Datta 2006; State Forest Report 2005). Also activities on non-forest lands are regulated mainly by the government's forest administration. However, the main supply of wood for the wood-based products that are manufactured in the private sector comes from non-forest sources, mainly from farmers who grow trees on farmland. The current national forest policy supports and encourages tree plantations on non-forest lands by the private sector. Government ceiling restrictions limit the implementation of large-scale industrial plantations. Thus, direct cooperation between industry and farmers is encouraged (Saigal *et al.* 2002). The main factors that determine the future of farm forestry are the availability of markets and the price policy for farm forestry products.

Officially, the forest area is classified in three categories: Reserved Forests (RF), Protected Forests (PF), and Unclassified Forests (UF). Approximately 23 percent of India's land area (77million ha) is officially classified as forest lands. An estimated 93 percent of the forest area is controlled by the Forest Department (FD) and 4 percent by the Revenue Department (RD). Only 1.5 percent of forests are under private ownership and another 1.5 percent is owned by corporate bodies and communities (Saigal *et al.* 2002). The forest cover is categorized in three classes: Very Dense Forest (VDF) with a canopy density of more than 70 percent, Moderately Dense Forest (MDF) with a density between 40 and 70 percent, and Open Forest (OF) with a density between 10 and 40 percent. The total forest cover in India as assessed in 2005 is 67.7 million ha which comprises 20.6 percent of the total geographic area. However, the land area under forest cover at present falls short of the target of the National Forest Policy (1988), which aimed at achieving a forest cover of 33 percent (87 million ha) of the land area by 2012 (IIASA 2009; Singh 2009).

The future of forestry looks brighter now than in the 1960s and 1970s when the forestry sector was competing with agriculture for land. The increase in future agricultural growth will primarily be based on increased productivity, which leaves more land available for agroforestry practices. Agroforestry possesses the potential to provide a secure income for the farmers in times of crop failure (Singh 2009). Another trend that can be identified for the Indian forestry sector is the value increase of NTFPs to the Indian economy, when compared to timber from forests. Meanwhile, around 80 percent of the timber required for the forest industry comes from trees outside the indigenous forests. There is potential to further increase the planting of trees outside the original forests in the future. The degradation and depletion of forests continues at present. However, this is not a specific forestry problem. The ever-growing demand on forest products and services is linked to population growth and poverty, especially among tribal people living in close proximity to forests (Nilsson 2008).

An important turning point in the history of forests and forestry in India has been reached: after a long decreasing trend in forest cover, the forest area (including planted forests) of the country is now increasing. This situation in India has been used as an example of the global "forest transition model", which seems to describe well the changes in land use and their associated effects on forest cover in different countries (FAO 2007, Angelsen 2008).

3. Theoretical framework

3.1. General remarks

The purpose of this chapter is to give some basic theoretical background for understanding the analytical concepts related to the central problems in this thesis. The framework is divided into four parts. The first part, on invasive alien species, discusses the problem of biotic materials that are transferred from their indigenous surroundings into an exotic environment. The focus is on plants that contain the potential to become invasive in a new environment. The second part, on wood fuel, highlights the consumption of wood used as fuel world-wide and provides basic definitions concerning wood, trees and forest terminologies. The third part outlines the framework of rural livelihood. The aim is to define the various assets of rural people and their possibilities to develop strategies that help in the improvement of their life conditions. The final section deals with the Hindu cultural classification of the environment. The Hindu cosmology is very complex and all nature is perceived as a manifestation of the Creator. Nature and God are inseparable so it is necessary to know about *dharma*, the Hindu's duty towards humans and nature.

3.2. Invasive alien species

Climatic changes and an increasing human population are responsible for changes in the availability of natural resources. We are witnessing, and participating in, a global restructuring of flora and fauna due to an increase in international trade and travel as well as climatic and land-use changes. In the search for new resources, exotic species that are known to provide benefits elsewhere have for a long time been introduced into new environments. Although these alien species may prove to be beneficial in multiple ways, providing food or protecting the environment, others may become invasive weeds, escaping proper management. Most invasions derive from deliberate or accidentally caused human actions and the species in question typically spread into markedly disturbed habitats which are strongly affected by human activities. However, there are also invasions into natural habitats which have been disturbed to some extent by natural processes (Williamson 1996).

Plant invaders - which are dealt with in this thesis - are capable of altering nutrient cycling, fire regimes, hydrology and energy budgets in a native ecosystem. In doing so, they diminish the number/diversity of domestic species or jeopardise their survival (Mack *et al.* 2000). However, there is only a low probability of successful invasions. The "ten-ten" rule states that 1 in 10 introduced species is able to establish itself, and 1 in 10 of those established species with self-sustaining populations become pests (Williamson 1993). The term "introduced" implies that the species is found outside control or cultivation as a potentially self-sustaining population. A species can be classified as "established" when a viable population is capable of persisting permanently if the habitat is maintained.

Alien (or non-native) plants face various constraints between the stages of seed dispersal and the production of new propagules. Evidence suggests that invasion (or propagule) pressure (in the sense of reproductive rate after invasion) is the most significant factor in the invasion process and that all communities are invasible, probably some more than others (Williamson 1996).

Plant invasions have been defined as being a consequence of both deliberate and unintentional human activity. Pyšek *et al.* (2004) proposes that the term invasion is only used where the distribution and abundance of plants change in relation to human activities. Changes in distribution ranges due to the retreat of glaciation are therefore not invasions. Such processes are described as "migration", "spread" or "range extension". Another case where the term "invasive" should not be used is for species that expand their distribution range and colonize new habitats in a geographical area native to them. In the definition of the Convention on Biological Diversity (CBD 2001), species are also classified as invasive when they are introduced outside their natural habitats as a consequence of human activity. Additionally, invasive species contain the ability to establish themselves after the invasion and out-compete natives, thus taking over the new environment.

The patterns of spread of invasive alien species are determined by the species involved, the environmental suitability for propagation, as well as the occurrence of extreme climatic events. In order to be classified as invasive, a plant needs to undergo three processes to survive in a successful manner:

1. Dispersal into a new locality (opportunity space),
2. Colonization and establishment (process of growing and reproducing successfully) in the new land, and
3. Enduring occupation of the habitat.

The successful occupation of a species in the new habitat needs to be perceived as problematic by humans in order to be labelled as invasive (Dekker 2005). The invader is likely to form small populations within the domestic flora for a period of time before it will rapidly increase its expansion in total population size and in number and size of individual infestations. At the end stage, the invader becomes a major problem (Sharma *et al.* 2005).

Dispersal, the process of the movement of an organism between locations, is recognized as one of the most important factors responsible for a successful invasion. Opportunity space, the available and habitable space (niche) for an invading plant, is the result of a change in local conditions which occurs as a consequence of disturbance (Dekker 2005). The increase in abundance in the invaded locality depends on the available niche opportunities that prevail in the new habitat, which depend on the ability of the invader (with its specific attributes) to respond to resource opportunities, opportunities to escape natural enemies, and the physical environment (Shea and Chesson 2002).

Although the climatic suitability for reproduction and survival are essential for the spread of invasive species, the presence of competing species and predators can have an overriding effect on a successful invasion (Sutherst 2000). It is therefore assumed that the escape from biotic constraints is a straightforward hypothesis that explains the success of an invader (Mack *et al.* 2000, Mooney, 2005; personal communication).[10] An invasive species entering a new continent, unaccompanied by its natural enemies, also known as "ecological release", allows the invader to reach a higher population density than in its native range (Sutherst 2000).

The introduction of *Eucalyptus* spp., which are native to Australia, into California at the end of the 18th century strengthens the argument about the initial lack of predators on invaders. Although the plantations were extensive, no damage to the leaves of Eucalyptus trees by herbivores was observed, whereas in their natural habitat the trees are attacked by herbivores. Scientists suggest

[10] Pullaiah 2005

that several species, once established in new surroundings, sooner or later reach equilibrium with the environment, with the effect of stabilizing the population (Mooney 2005).

Natural ecosystems are limited in adjusting to alien invasive species and the prevention of an uncontrolled spreading will require human intervention. More than 150 nations signed the Convention on Biological Diversity (CBD) at the 1992 Earth Summit in Rio de Janeiro. In article 8, in-situ conservation, the contracting parties are called to

> *"Prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species"* (CBD 2001, 149).

In assessing the ecological consequences of invasions the ten-ten rule implies that most invaders have minor ecological effects. However, some of the biological invasions have tremendous negative effects on the ecosystem. The impact of plant invasions affects individual plants as well as the population dynamics of native species. It also affects community dynamics like species richness, diversity, trophic structure and ecosystem processes and functioning (van Wilgen *et al.* 2001).

The impact of biotic invasions can be estimated in the loss of economic output, like losses in crop production, or through estimating the costs of combating invasions, such as eradication. Once they become self perpetuating and uncontrollable, invading large areas, eradication of established invaders is rare and control efforts vary in economic costs and effectiveness. Control options are traditionally evaluated by using benefit-cost analysis, as suggested by Arrow *et al.* (1996). In evaluating the costs and benefits of invasion control it is important to identify all the possible impacts of IAS (Perrings *et al.* 2005; Laxén 2007).

3.2.1. Valuation

Ecosystem services are associated with processes in natural ecosystems that derive some benefits for humanity. Those benefits include the prevention of soil erosion and the production of fertile soils. They include also the regulation of the hydrological cycles and the recycling of waste products, as well as pollination and the preservation of the earth's genetic library. Today there is a demand for a clear quantification of those services according to their monetary value (van Wilgen *et al.* 1996).

Most of the literature dealing with the economic analysis of invasions of alien species uses cost-benefit methods to estimate damages from invasions. The so-called *ex post* analysis is a helpful method used to identify economically feasible control strategies that minimizes the cost of controlling an estimated degree of damage. *Ex ante* analysis compares the cost and benefits of strategies that allow invasions to happen with those that prevent them. The aim of this type of analysis is to compare the benefits and detriments for different groups of people with either kind of strategy, which helps to decide the plan of intervention for an optimal level of satisfaction. In the *ex ante* cost-benefit analysis, it is essential to understand the effect of an invasion on ecosystem services like water supply, pest control or pollination, and how it affects economic activities such as agriculture or ranch management. The services and economic activities of the species then need to be evaluated in monetary terms (Naylor 2000).

The values estimated in a cost-benefit analysis include direct-use (consumption and non-consumption) values, indirect-use values, and non-use values. Direct-use values can be identified

with specific market-based goods and services (urban water supply, livestock, or crops) and reflect a monetary worth. Indirect-use values include ecosystem services that are lost because of invasions; their value is estimated by replacement costs. A replacement cost, for example, is the cost that is calculated for the replacement of a naturally available water supply by alternative water supply systems. Non-use values are those assigned by people to a species or an ecosystem that they may not directly or indirectly use but for which they are willing to pay in order to protect them (Naylor 2000).

An example of the valuation of ecosystem services is the case study of South African *fynbos* (a Mediterranean-type shrubland) ecosystems. The *fynbos* vegetation is invaded by non-indigenous woody trees and shrubs which replace the native *fynbos* and increase the biomass by between 50 and 100 percent, resulting in heavy water use by these invasive trees and shrubs (mainly *Hakea* spp. and *Acacia* spp.) and in significant decreases in runoff from catchment areas. Those species were introduced to South Africa to provide fast-growing timber and to protect the area from shifting dunes. The increased above-ground biomass resulted in increased fuel loads and therefore in fire intensity. The replacement of the native vegetation has increased erosion through a reduced capacity to cover and protect the soil after fires. The drying up of some of the rivers, or the infrequent flow of others, has reduced agricultural production. The whole process has threatened many endemic plant species with extinction (van Wilgen *et al.* 1996).

In the economic evaluation of water and catchment management, van Wilgen *et al.* (1996) compared the costs and water yields in two identical catchments, one with and one without the management of alien weed populations. Assuming the annual interest costs on capital outlays (building of a water supply facility in both cases and the initial clearing of alien plants in one), together with annual operation costs, the calculated unit cost of water production was 14 percent lower for the case in which alien species were managed. Furthermore, the same study estimated that the watereshed would yield 30 percent more water naturally, if the alien species were managed. In addition to the benefits of cheaper water delivery, optimal catchment management provides additional ecosystem services, such as the economic exploitation of indigenous *fynbos* plants and ecotourism opportunities. Besides those calculated monetary values there is still the value of an ecosystem which stands regardless of its actual or potential use.

The above cost-benefit analysis showed that the removal of alien invasive plants maximised economic efficiency, had advantages for ecosystem stability and biodiversity conservation, and a possibility for job creation through clearing operations of alien plants. Those results were communicated to the Minister of Water Affairs of the government of South Africa in 1995 and the immediate response was the initiation of the program “Working for Water” (van Wilgen and Le Maitre 1998).

3.2.2. Invasive forest tree species

Most of the introduced alien trees have been intentionally transplanted beyond their native ranges to a new biotic environment for expected benefits. There are a few alien tree species that have become fundamentally important for commercial plantation forestry. Afforestation in the southern hemisphere, especially with eucalyptus and pines, has increased dramatically during the last decades for the supply of round wood and pulp (Richardson 1998). There is a large area of wasteland in India as well as in other countries that could be economically reclaimed and ecologically improved by afforestation (Balooni 2003). Beside commercial forestry, there has been

an increased use of alien trees in non-conventional forestry, especially in developing countries. A shortage of fuelwood, together with increasing environmental degradation, soil erosion and desertification, promoted the use of exotic woody shrubs and trees, in particular woody legumes, during the 1970s and 1980s. Woody legumes were favoured because of their ability to grow rapidly under extreme climatic conditions and on poor soils. Some of the most preferred trees were *Acacia*, *Leucaena*, and *Prosopis* species (FAO 2003).

Although alien invasive species have been defined by the CBD as mentioned above, a few authors proposed slightly different definitions of invasive trees/woody shrubs. Binggeli (1996) defines the term invasive (naturalised, neophyte, adventive) for woody plants as the establishment of self-generating and most often expanding populations of introduced species. Whenever possible, invasive species in a free living state in nature are scored according to their capacity for being potentially moderately or highly invasive.

Another definition includes the word "alien" and the expected impact of the invasive plant. Here an invasive plant is defined as

> *"…an alien plant spreading naturally (without the direct assistance of people) in natural or semi-natural habitats, to produce a significant change in terms of composition, structure, or ecosystem processes"* (Cronk and Fuller 1995, 1).

Because of the many positive aspects of alien invasive woody plants in forestry or agroforestry, the definitions above are suitable to use in this thesis. Here, the impact of the invasive species is not preconceived, while in the definition of the CBD (2001) the emphasis is on the threat to native biodiversity, which considers the overall impact of invasive species as negative.

Introduced invasive woody plants always have some kind of impact on the environment, affecting the structure and functioning of the invaded ecosystems. These impacts are difficult to classify into positive or negative because the opinion of the observer is influenced by cultural, political, social, and employment background. While foresters assess the regeneration of an exotic desired timber tree as positive, and the regeneration of an invasive exotic weed as negative, to a manager of "natural" ecosystems any introduction of alien species is experienced as negative (Goodland *et al.* 1998).

When looking at the negative impact of invasive alien trees or shrubs it is necessary to ask in which way they affect the native vegetation. Does the invader affect the regeneration of rare or endangered plant species in regions of high species richness? Further, it is necessary to investigate if and to what extent the invader alters nutrient and hydrological cycles, light regimes, and fire susceptibility. In assessing how the invader affects human activity the questions are: does the plant create physical barriers to humans, does it create health problems, is the plant poisonous to livestock, or will it become a weed on agricultural, forestry, or pasturland (Sharma *et al.* 2005).

The positive effects of invasive woody plants are sometimes overwhelming and may have an important share in the local economy. The people's perception and valuation of the plant needs to be considered. The species that have been introduced in agroforestry have been selected for many qualities, including soil protection, fuelwood supply and pods as fodder for livestock (Muthana 1985; Pasiecznik *et al.* 2001). Species of the genus *Prosopis* are among the most adaptable and fastest growing trees in the tropical arid and semi-arid regions. Prosopis used as shelterbelts in the arid and semi-arid areas of the Sudan has proved to provide important protection from invading sand dunes. Before shelterbelts were established, many families had to abandon their homes and

move to other places because sand started to invade their houses, ultimately making it impossible to live there (Laxén 2007).

Prosopis has become invasive and has spread throughout the tropical arid and semi-arid regions of India. More than 70 percent of the prosopis stands in those areas are regenerated naturally and satisfy the demand for fuelwood and fodder for a growing human and livestock population. At the same time, it poses the threat of invading fertile agricultural lands (Tewari *et al.* 2000). Since eradication of the tree has shown to be difficult or almost impossible in many parts of the world, there is only the option of managing the naturally regenerating stands (Pasiecznik *et al.* 2001).

3.3. Wood fuel

3.3.1. Definitions

In order to gain a proper understanding about the production and distribution of wood, fuel it is appropriate to clear up some definitions. The FAO (2001a) defines wood fuels as consisting of three main products: *fuelwood, charcoal, and black liquor*. Fuelwood and charcoal are extracted from natural forests and plantations, other wooded lands, or from wood outside forests. Indirect wood fuels consist of by-products derived from wood processing industries, like sawmills or pulp and paper mills and recycled wooden products. Recovered wood fuels are defined as wood that is used directly or indirectly as fuel and is derived from economic activities outside the forest sector. Black liquor is obtained in the production of sulphate or soda pulp during the process of paper production. Other wood fuels are fuels derived from fuelwood and charcoal, such as methanol. Wood fuels include almost the entire tree or shrub with stems, branches, twigs, and roots and the non-woody leaves used as fuel. The term fuelwood refers to twigs, branches and stemwood.

Forests are defined by the FAO as an area of more than 0.5 ha with a tree cover of more than 10 percent, or trees being able to reach these thresholds *in situ* (FAO 2005). "Other wooded lands" consist of areas larger than 0.5 hectares with a tree cover of 5 to 10 percent and a minimum height of 5 m, or able to reach these thresholds *in situ*; or with a cover combined of trees, shrubs, and bushes of more than 10 percent. Both forests and "other wooded lands" exclude land that is predominately under agricultural or urban land use (FAO 2005). "Trees outside forests" include both trees and shrubs but are not covered in the definition of forests or other wooded lands (FAO 2002b). Trees outside forests include agroforestry systems, orchards, plantations alongside roads, canals, ponds and lakes, and trees in urban areas near houses, as well as ornamental trees.

In the past, wood-based fuels, like firewood and charcoal, have been the primary fuels in the rural areas of the industrialized nations. Today, they are often replaced by more convenient sources of fuel, such as coal, gas, or electricity. However, in developing countries, especially in the rural areas, wood has remained the dominant fuel (Trossero 2002). The use of wood as a domestic energy does not require complex, expensive equipment and it can be procured outside the monetary economy (Arnold *et al.* 2003).

Wood fuels currently represent about 7 percent of the total worldwide primary energy use. In the developing countries, with 77 percent of the world's population, the consumption of wood fuels amounts to 76 percent, and the biggest share of total wood fuel consumption is in Asia, with 44 percent (Figure 2).

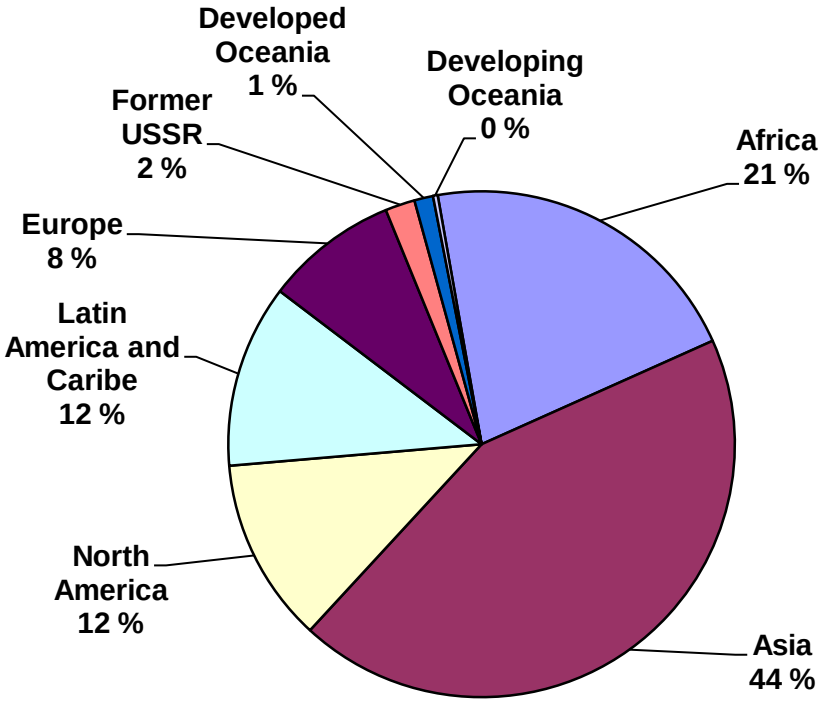

Figure 2. Distribution of wood energy consumption by region in 1995 (FAO 2002a).

In the developing countries, more than 2 billion people are dependent on wood fuel for daily cooking and heating. In 34 countries in those regions, wood fuels provide over 70 percent of their energy needs (Trossero 2002).

3.3.2. The assumed "fuelwood crisis" of the 1970s and 1980s

In the 1970s, a "fuelwood gap theory" was formulated and many international organizations were anxious that the energy supply of most of the poor people in the developing countries, with about half of the world's population, would suffer a lack of wood fuel. In a publication by De Montalembert and Clément, "Fuelwood supplies in the developing countries" (FAO 1983), the fear was raised that the rapid population growth would negatively affect the fuelwood supply among the poor in the developing countries. It was believed that fuelwood and charcoal consumption was due to the extraction of fuelwood from forest resources and the use of wood as fuel was believed to enhance the vicious circle of poverty and resource degradation. There was a concern that people were using more fuelwood than was being regenerated by forest growth. However, the "fuelwood crisis" predicted for the 1980s never materialised (RWEDP 1997; Trossero 2002).

In the 1980s, the supply situation of fuelwood was grossly underestimated due to the fact that yield figures were connected to forest resources, whereas most of the fuelwood is taken from woody plants outside forests, such as bushes, shrubs, or farm trees. They mostly regenerate naturally. Fuelwood is not only gained from felling trees, but is also taken from deadwood, from pruning or looping, and other sorts of wood harvesting. Much fuelwood from felling trees was taken from land that had been cleared for agriculture (Arnold *et al.* 2003).

In a study of seven Asian countries (RWEDP 1997), it was shown that only one-third of wood energy is taken from forests while two- thirds of fuelwood originates from outside forests (common lands, farms, plantations, etc.) and from other wood and agricultural waste resources (wood processing residues, reuse of wood, woody crop residues, etc.). In total, one third of all the energy that is consumed in developing countries is produced from bio-fuels like wood, crop residues, and animal dung. This is equal to an annual bio-fuel consumption of 1 billion tons of oil equivalent (btoe) (Barnes and Floor 1996).

New analytical models for the prediction of fuelwood consumption estimate that the peak of global annual consumption was reached by the mid-1990s at a level of 1,600 million cubic metres (Arnold *et al.* 2003). The global consumption of charcoal, on the contrary, is increasing. There are differences in wood fuel consumption in different regions of the world. The consumption of fuelwood in Southeast Asia has declined since the 1990s with little change expected for the near future. Charcoal consumption in Africa is steadily increasing, which is also the case for South America (Table 2, Table 3).

3.3.3. Trees outside forests.

Trees growing outside forests as defined by FAO (2002b) are trees that grow on agricultural land, in human settlements, and on bare land (former mining areas or dunes). Trees outside forests include agroforestry systems, small woodlots, and orchards. Trees may grow in pastoral areas on farms, along rivers, irrigation canals and roadsides, in urban areas and towns, as well as in home gardens and parklands (FAO 2001b).

The United Nations Conference on Environment and Development (UNCED) in Rio in 1992 placed environment, sustainable development, and biological diversity high on its agenda. Trees, and trees outside forests in particular, have been recognised for their contribution to social welfare, the economy and the environment. Among many other characteristics, they play a major role in household economics. They provide the households with food products such as fruits, seeds and honey, as well as fodder and browsing for their livestock. Non-food products include fuelwood, fibre, medical products, and many more. Trees outside forests also provide direct services like shade, windbreaks, living fences and ecosystem conservation. Further, they offer indirect services such as job creation, market opportunities, and the development of industries and artisan sectors (FAO 2002b).

Table 2. FAO projections of fuelwood consumption in the main developing regions, to 2030. (Broadhead *et al.* 2001).

Fuelwood (million cubic metres)							
	1970	**1980**	**1990**	**2000**	**2010**	**2020**	**2030**
South Asia	234.5	286.6	336.4	359.9	372.5	361.5	338.6
Southeast Asia	294.6	263.1	221.7	178.0	139.1	107.5	81.3
East Asia	293.4	311.4	282.5	224.3	186.3	155.4	127.1
Africa	271.1	305.1	364.6	440.0	485.7	526.0	544.8
South America	88.6	92.0	96.4	100.2	107.1	114.9	122.0
World*	**1444.7**	**1572.7**	**1611.6**	**1616.2**	**1591.3**	**1558.3**	**1501.6**

*Observe the decline in consumption beginning in 2000.

Table 3. FAO projections of charcoal consumption in the main developing regions, to 2030. (Broadhead *et al.* 2001).

Charcoal (million tons)							
	1970	**1980**	**1990**	**2000**	**2010**	**2020**	**2030**
South Asia	1.3	1.6	1.9	2.1	2.2	2.4	2.5
Southeast Asia	0.8	1.2	1.4	1.6	1.9	2.1	2.3
East Asia	2.1	2.3	2.3	2.2	2.1	2.0	1.8
Africa	8.1	11.0	16.1	23.0	30.2	38.4	46.1
South America	7.2	9.0	12.1	14.4	16.7	18.6	20.0
World	**21.2**	**27**	**35.8**	**45.8**	**55.8**	**66.3**	**75.6**

3.4. Rural livelihoods

3.4.1. A framework for the analysis of rural livelihoods

Prosopis plays an important role in the livelihood of the rural people of South India. The theoretical framework that is used to analyse rural livelihood helps in assessing how essential this tree is for the rural households in the drylands, where resources are scarce.

Livelihood in its most simple meaning is a way of obtaining a living. One of the popular definitions of sustainable livelihood (SL) articulates that a livelihood

> *"…comprises people, their capabilities, assets (stores, resources, claims and access) and activities required for a means of living: a livelihood is sustainable which can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation; and which contributes net benefits to other livelihoods at the local and global levels and in short and long term"* (Chambers and Conway 1992, 6).

Several other authors dealing with rural livelihood issues have used this definition with minor modifications (Hussein and Nelson 1998; Scoones 1998). In the definition of livelihood by Ellis (2000), the emphasis is placed on the links between the access to assets and the option of people (determined by gender, class, kin, belief system) to pursue alternative activities which are capable of generating income levels required for survival.

The important attribute of the livelihood approach is to understand the status of the assets, and the access to assets, which provide the options that determine the livelihood strategy of the individuals or households. Assets are the foundations on which households build to undertake production, obtain employment, and participate in reciprocal exchanges with other households. Assets are the resources that can be utilized to produce the revenue that enables households to survive or sustain a certain level of material well being (Ellis 2000). According to the definition of the DFID (1999), there are five categories of assets or capital endowments: natural, social, human, physical and financial.

> *Natural capital:* Refers to the natural resource stocks (land, water, trees) from which resource flows and services (e.g. protection from erosion, nutrient cycling) are produced and utilized by humans for their survival.
>
> *Social capital:* Refers to resources like social networks and associations upon which people rely and gain support that contributes to their livelihood.
>
> *Human capital:* Refers to the labour available to the household (education, skills, ability to work and health status) which enable people and households to engage in different livelihood strategies to achieve their livelihood objectives.
>
> *Physical capital:* Refers to the basic infrastructure and assets accomplished by economic production processes, like machines, tools, irrigation or energy supply.
>
> *Financial capital:* Refers to available stocks of cash or regular inflow of money that enables people and households to purchase consumption or production goods.

The assets are shown in a pentagon shape (Figure 3) which illustrates the different resources that people have access to (DFID 1999; Scoones 1998). The centre of the pentagon represents zero access to assets, while the outer shape represents maximum access to assets. Different shaped pentagons can be drawn for different social groups because asset endowments change over time (Carney 1998).

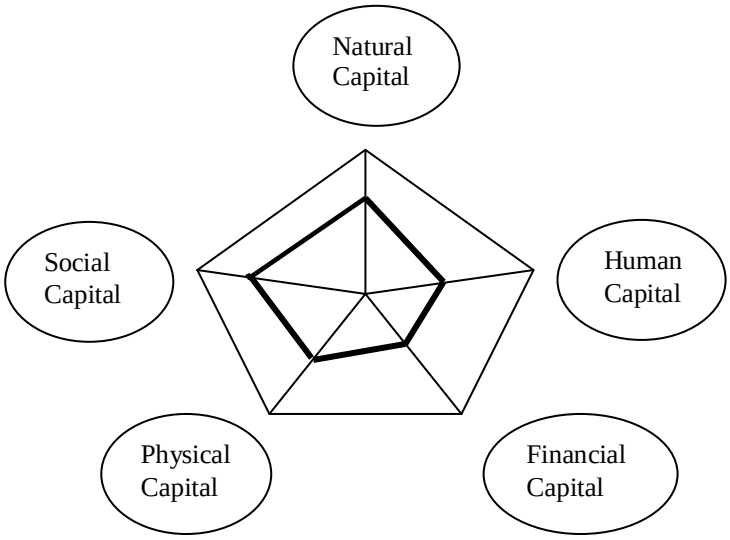

Figure 3. The asset pentagon. (Modified from Carney 1998).
The inner circle displays a household which is endowed with high social and natural capital, moderate physical capital and low human and financial capital.

The Sustainable Rural Livelihood (SRL) framework emphasises that the transforming structures and processes (institutions, policies and legislation) determine the access to various types of capital. According to Carney (1998), it is important to understand the *vulnerability context* (trends, shocks and local cultural) in which assets exist. People's access and control of resources are affected by:

- Trends in: population growth, resources availability and conflicts, national and international trades, governance and politics, agricultural technology, growth of non-farm activities in rural areas and the economy as a whole;
- Shocks and events related to human health problems, natural disasters like earthquakes, droughts, flooding, pests (of crops and livestock), conflicts like civil wars, and economic shocks;
- Seasonality of production, employment opportunities, prices or health (Chambers and Conway 1992; Scoones 1998; DFID 1999).

Trends have influence on economic rates of return and may be less harmful due to their predictability. Shocks, such as natural disasters or civil conflicts, can destroy assets directly and force people to leave their home and land as part of their coping strategies. Seasonal shifts in

employment opportunities, food availability and prices cause the most hardships to people in developing countries (DFID 1999). The vulnerability context is also about the way people and households adapt and manage trends, shocks and stresses.

It is vitally important to gain an understanding of the structures (organisations, from levels of government to the private sector) and processes (laws, policies, culture, institutions) which provide the link between the micro (individual, household, and community) and the macro (regional, government, private enterprises) levels (Ellis 2000; Scoones 1998). The extent to which assets can be converted from one type into another, for example, from natural to financial capital or from human into physical capital, are influenced by markets and legal restrictions (Carney 1998).

3.4.2. Livelihood strategies

People try for a livelihood strategy that provides a range of outcomes that will improve their well-being and reduce poverty. Livelihood strategies are influenced by traditions and the vulnerability context under which they function. Ellis (2000) proposes a division between natural resource and non-natural resource based activities. The former include collecting or gathering (e.g. wood fuel or NTFPs from woodlands and forests), livestock, crop cultivation (food or non-food cash crops), non-farm activities (such as brick production, weaving, and charcoal making) and pastoralism. Non-natural resource based activities include marketing and trading farm products or consumer goods, rural services or manufacture (barber, carpentry, etc.), remittances from migrated family members, or state pensions from previous employment. Another proposal suggests that rural people construct their livelihood by the using three main strategies: agricultural intensification/extensification, livelihood diversification and migration (Scoones 1998; Hussein and Nelson 1998).

The choices people make are of course dependent on the different assets they possess. Chambers and Conway (1992) point out the initial predetermination of various livelihood strategies. An individual's access to assets is predetermined by birth through inheriting land, trees, or livestock. In India, a child is born into a caste with an assigned role that decides the future profession of the individual, for instance, as a potter, washer, fisherman, or shepherd. Those people who are generally better off also have a wider scale of assets to choose from during periods of economic growth. Still others – and this is true in India as well - may improve their livelihood through education or migration (Chambers and Conway 1992).

3.4.3. Livelihood diversification

Livelihood diversification enables households to protect themselves from environmental and economic shocks. The determinants of livelihood diversification are often divided into necessity or choice. Necessity includes involuntary reasons of distress. It might be the deterioration of an environment, natural disasters, civil war, or anything resulting in the abandonment of previous assets that forces a household to diversify. Choice, on the contrary, refers to voluntary reasons for diversification, such as accumulating wealth to invest in farming technology or investing in the education of children in order to improve their possibilities to obtain good jobs (Ellis 2000).

Based on empirical evidence and supported by the literature, it can be stated that livelihood diversification helps to reduce rural poverty and makes households less vulnerable to trends and

seasonality. Diversification enables individuals and households to reduce their vulnerability by building assets that enable them to build their own way out of poverty. Diversification is also a way to improve the quality and sustainability of natural resources, which is important for the sustainability of a livelihood over time (Ellis and Allison 2004). However, Hussein and Nelson (1998) do not see livelihood diversification only in the context of the choice to build routes out of poverty. They argue that an increase in various diversification strategies does not necessarily mean the achievement of a more sustainable livelihood. Rather, it is a sign of long-term adaptation by poor farmers to seasonable stress, shocks and poverty, with the aim to survive in an increasingly vulnerable world.

In economic terms, the income from agricultural labour varies during the year both in on-farm and off-farm activities. On-farm activities reach their highest peak during the rainy season when fields are under cultivation and during the harvesting times. Off-farm activities take place when little or no activity is done in the fields. During that time there is work in distributing grain to markets, storing grain, or harvesting wood to sell or to use privately as fuelwood. Thus the collection of wood and forest products for sale supports the household income and represents an alternative to day labouring for poor people (Seppälä 1996).

It is widely recognized among researchers that the use of diverse income sources is common among all income classes. However, there are recognizable differences between the kind and nature of the diversification activities between poorer and better-off households. Households with better access to various assets often diversify their income by engaging themselves, for instance, in non-farm business like trade, keeping a tea shop, owning a general store or making bricks. The most disadvantaged and vulnerable households, with poor education, low status and wealth, small household size, and long distances to markets, are usually also least able to gain access to the non-farm economy (Readon 1997; Ellis and Allison 2004).

Poorer households diversify their income through casual work as labourers in agriculture mostly for other farms, which keeps them highly dependent on agriculture (Ellis and Allison 2004). In Malawi, the need for cash makes poor households work for other farms and causes them to experience labour shortage on their own farm. As a consequence, they are forced to neglect their good cultivation practises and adopt unfavourable strategies like late planting or the neglect of weeding. This leads to lower yields and lower income, and contributes to household food insecurity and the continuation of the vicious cycle of poverty (Alwang and Siegel 1999).

One of the features that all rural households are confronted with is seasonality. In India, agricultural activities start with the onset of the monsoon, and the rainy season determines the length of the growing season. Seasonality affects land owners as well as poor landless people who depend on agricultural labour. The rainy season, which occurs from the onset of the rains until the harvest, is the worst time of the year for agriculturalists in the tropics. Poor people especially are vulnerable to malnutrition, hardship, sickness and death. During the wet season, rural health services are least effective and the demand for agricultural labour is highest (Chambers 1982).

3.4.4. "Investmment poverty"

Rural poverty is commonly related to the non-access of land that can be cultivated in a sustainable manner. Those people who experience social marginalization, the exclusion from sustainable livelihood and poverty, are dependent on access to common property resources (CPR) because of the lack of land that would support their subsistence needs (Beck and Nesmith 2001).

Readon and Vosti (1995) analysed links between rural poverty and the environment by differentiating between "welfare poverty" and "investment poverty". The level of poverty decides the poverty-environment links. Being "welfare-poor" is not to be "absolutely poor" in a consumer-orientated definition, but it means that people are too poor to accumulate surplus above the minimum diet line in order to make any investment in conservation or intensify their land use practises. Such investments would be necessary to maintain a sustainable income without destroying the resource base. Scientists therefore suggest using the term "investment poverty" for the analysis of links between poverty and the environment. According to the definition, very poor households do not have the ability to

> *"…make minimum investments in resource improvements to maintain or enhance the quantity and quality of the resource base – to forestall or reverse resource degradation"* (Readon and Vosti 1995, 1498).

In order to be able to reduce poverty and at the same time enhance the resource base it is necessary to understand the assets available to the households. Often there are not even minimum monetary resources to invest in the improvement of their resource base, be it in the form of improving the house and farming equipment or the use of fertilizers.

3.5. Traditional Hindu classification of the environment

3.5.1. General remarks

India is a non-Western, but highly developed, old civilization, with a complex cosmology that classifies trees and guides people about how to relate to nature. In Indian culture, economic decisions do not carry the same weight as in Europe or the US. Indigenous trees that are considered sacred simply remain outside economic usage even though there could be a high demand for them as raw materials. Exotic tree species, like prosopis, are not generally considered sacred, although they are occasionally promoted to the stage of being the residence of deities. Although prosopis is part of the overall sacred nature, compared with the traditional indigenous sacred trees it occupies a significantly lower level in the classification system. Thus prosopis can be used for the livelihood economy.

3.5.2. Hindu cosmology and the Vedas

In India, more than 80 percent of the population are Hindus which accounts for more than 600 million people. The Persian term Hindu derives from the River Indus. It refers to the people living around and along the *Sindhu* River, as it was called by the Aryans during the Vedic times. During the Greek occupation, which followed the Persian in the third century BC, the new invaders called

the great river *Indos* and the people living there *Indikoi*, the origin of the contemporary term India and Indians. With the increase of Muslim contacts, the writings about those Indian people increased. The Muslim observer, al-Biruni, wrote an account of the Hindu way of life (around 1030 AD) in which he describes the life of the Hindus. He sums up the term Hinduism as the Brahmin way of life. The so-called "Brahmanic culture", which can be understood as the beliefs and practices propagated by Brahmin authority, dominated the life of the Hindus for a long time. Brahmanic culture, in turn was propagated through the sacred language of Sanskrit (Lipner 1994).

The Hindu understanding of nature was to a great extent shaped by the Aryans. They had a strong influence on Hindu life and they established the Sanskrit language. The Aryans created the Vedas (Veda means knowledge), the world's oldest literature. The Vedas were followed by writings of later periods like the Brāhmaṇas, Āraṇyakas and the Upaniṣads (Lippner 1994; Choudhury 1998a). The medium of communication in Hinduism was the word, the oral transmission of the sacred word, the Veda. The sacred texts of the Hindus are referred to as *śruti* ("what is heard"). *Śruti* has no author but it is said that it is a divine recording of the "cosmic sounds of truth", heard by saints or sages. These texts are not classified for any time span. They begin with some of the earliest texts known in Hinduism and continue until the later periods of the Upanisads. The four Vedas are the Rig Veda, the Yajur Veda, the Sāma Veda, and the Atharva Veda. Each Veda is traditionally divided into the following segments: Saṃhitā, Brāhmaṇa, Āranyaka, and Upaniṣad. Among the most important texts in Hinduism are also the Puranas and the epics, Mahābhārata and Rāmāyana (Lippner 1994).

The Vedas that were composed nearly four thousand years ago are still regarded by many Indians as the highest authority for their religion, morals and philosophy. The ancestors listened to the songs of the Vedas that told them about bright powers above and about the life to come after leaving the present one (Müller 1867). The Vedas provided a stratum of ancient thought, feelings, hopes, joys, and fears; the foundation of ancient religion. The purpose of the ancient hymns was to persuade the Gods by praise accompanied with ritual offerings; basically an oblation of *soma*[11] juice and the fire sacrifice of melted butter. The gods to whom these rituals were offered were largely personifications of the powers of nature. The society of the Vedic times consisted mainly of herders who were very dependent on, and vulnerable to, the forces of nature. The songs and the accompanied sacrifices were a means to win the favour of the nature gods and thus control untamed forces (Macdonnell 1917).

The Hindu attitude towards nature has been shaped by their religious views of the cosmos and the creation. Hindu religion played a crucial role in the way people were educated in relation to their environment. In the Hindu tradition of thought nature is an inseparable part of embodied human lives. In the ancient Hindu scriptures starting from the Vedas, and later on followed by the Upaniṣads, or the Mahābhārata, the atmosphere, the earth, plants, animals, and humans (the whole cosmos) were parts of God's body, and thus divine. Due to its divinity, respect towards nature is demanded from humans (Dwivedi 1990).

The Vedic tradition teaches that the microcosm of the human individual body resembles the macrocosmic body, the mode of self-expression of the supreme being. In relation to the macrocosm, the five subtle elements are associated with the five senses which are the doorway to human intelligence and knowledge. The attribute of space is related to sound; air is connected with sound and touch; fire consists of sound, touch and colour; water adds taste to the other three and earth has odour as the additional fifth attribute. Accordingly, the Vedas teach that nature and environment are

[11] *Soma*: juice of an unidentified sacred plant which was a fundamental offering of the Vedic sacrifices.

inseparable parts of human existence (Rao 2000). There is no division between the sacred and the secular. Everything in nature is sacred; nature is sacred. The *sarva bhūta hitā,* which means caring for the common good, the well-being of people and other creatures, and the protection of the environment, are duties to be applied in every Hindu's life. It is a Hindu's duty towards humanity and God's creation (Dwivedi 2000).

Trees have provided a source of food, like fruits and roots, fodder, timber, medicine, and shelter since the earliest times. The worship of trees started before people developed agriculture and it is thought that through the worship of trees, humans attempted to propitiate God. In India, clear signs of tree worship were found between the third and fourth millennium BC, among the people living in the Indus valley (Sinha 1979). Before trees were cut down, Vedic priests sung verses to persuade the deities, which were believed to have their residence in those trees. Trees were, and are still, praised for qualities like generosity, bounty, nourishment and abundance (Nugteren 2005).

3.5.3. Dharmic ecology in Hinduism

A significant part of Hindu literature is dedicated to the guidance of people in the practise of *dharma,* the righteous path. *Dharma* is a cosmic law that refers to the duty of human beings to their family, to society, humanity, nature and towards God. *Dharm*a has as its purpose the conservation and maintenance of the society and the whole world. Following the law of *dharma* is meant to lead towards worldly development and spiritual fulfilment. For a Hindu, Brahma is the Supreme Being and the ultimate source and course of all beings in creation (Dwivedi 1990).

Ṛta and *dharma* deal with the totality of moral and physical order in nature and life. *Ṛta* in Vedic Sanskrit literally means "the order or course of things" and *dharma* is also translated as "that which upholds or supports" (from the root *dhr*-to hold). The symbol of *dharma*, the wheel, is on the state flag of India. Teachings and lessons in *dharma* were traditionally handed down over generations through storytelling. The lessons about *dharma* in the epics of Rāmāyaṇa and stories in the Mahābhārata and the Purāṇas were, and are still today, expressed through theatre and dance performances (Rukmani 2000).

The inspiration and background of sacralising trees, forests, or rivers is found in the traditional Hindu literature beginning from the early Vedas. Many of the traditional Hindu texts and scripts were only available to the literate priest caste of the Brahmins and not to the common people. While the epics Rāmāyana and Mahābhārata and many Purānas were known to the ordinary people through oral traditions, the philosophical works of the Upaniṣads were mainly studied by the educated Brahmins. Texts on *dharma* were known only to a minority of Brahmins but the concepts of *dharma* were transmitted to the public through stories narrated by family and village elders. While the *tattva* texts, which were known mainly by gurus or holy men, deal with the concept of the liberation of the human soul, the *dharma* texts are more concerned with worldly behaviour (Narayanan 1997).

Dharma is also connected with *karma* which literally means "deed" or "act" and in a broader sense applies to the universal principle of cause and effect. Each deed or act performed creates a chain of reactions or consequences called *karma phala* (fruits, or effects, of action).

Hinduism differentiates between three types of *karma*:

1. *Sanchita karma* (accumulated), the total sum of past *karmas* that are not yet resolved;
2. *Parabda karma* (fruit-bearing), the part of the *sanchita karma* which is going to be experienced in the current life; and
3. *Kryamana karma* (current), the karma that humans create today, which will bear fruit in the future.

Thus every action creates a reaction and it is important to chose a right (*dharmic*) action which will produce positive and beneficial results. The law of *karma* concerns acts between humans and also between humans and nature. Uncontrolled exploitation of nature and its natural resources consequently adds negative *karma* to any person responsible for it (Dwivedi 2000). Hinduism teaches humans to respect and live in harmony with nature, a teaching that has had great influence on the philosophies of Buddhism and Jainism also.

The Hindu conception of God is both monotheistic, seeing God as a single divine person, and polytheistic, contemplating the divine as one in many. For Hindus, nature and God is an inseparable unity. In Indian Sāṃkhya philosophy, cosmic matter (*prakṛti*) is described as the matrix of the material creation, a bundle of energy. It consists of three qualities, known as *guṇas: sattva* (lightness, purity), *rajas* (passionate activity), and *tamas* (lethargy, heaviness). *Sattva* refers to the quality of balance, stability and equality and includes the capacity of happiness. *Rajas* is the mobile force that generates activity, change and disturbance. *Rajas* is associated with motivation and expression and its inherited centrifugal force causes dispersion and disintegration, and finally results in pain. *Tamas* is the immobile and heavy quality that causes destruction and lack of perception. *Tamas* is the cause behind degeneration that results in delusion and confusion. *Prakṛti* is held together by the three *gunas* which are bound together as one force with different aspects. They keep each other in balance, being mutually supportive and productive (Pole 2006).

The five great elements, which are earth (*pṛithvī*), air (*vāyu*), space (*ākāśa*), water (*ap*) and fire (*tejas*), evolve out of the cosmic matter (*prakṛti*). In the Vedas and the Puranic literature the five great elements are described as the causes of creation. They contain the omnipresent elements that enclose the creative potential and constitute Brahman, the manifestation of the earth. They create, sustain and nurture all life and after death they absorb what was created before (Rao 2000; Pole 2006).

Brahman penetrates into the universe as its life and consciousness. Because God has the absolute sovereignty of the whole creation, no harm should be done to any of the species in nature and all that exists is of the same value and should be treated equally. The Pṛthivī Sūkta hymn declares that the richness and fertility of mother earth is meant for everyone equally and humans are asked to preserve nature so it can serve future generations. Humans are urged to always speak graciously about mother earth and pay respect to her. The foremost duty is to protect, preserve and care for the environment.

State and environment

Classical Indian texts on polity, kingship and state responsibility, such as Kauṭilya's Arthaśāstra, contained guidelines about how nature and natural resources should be taken care of (Shamasastry 1915). The texts have greatly influenced the way people treated their environment and provide good

examples of environmental management in India during the times of the great kingdoms, the "Age of Empires" from 500 BC-AD 300 (McGee 2000).

The Arthaśāstra text (dealing with rules and orders of the ksatriya varna) guided kings and state leaders in the appropriate manner of environmental protection and maintenance of natural resources for the sake of the spiritual and material wealth of the state and the well-being of its people. The Arthaśāstra (Shamasastry 1915) described in detail how farming should be done to provide the most benefits, giving information about crop rotations and irrigation facilities which is still relevant for contemporary environmentalists.

In the Arthaśāstra (Shamasastry 1915), various forms of cultivation, including farming methods using manure and compost as fertilizers, were described. Kauṭilya described also the protection and the sustainable extraction of natural resources. Some of the important resources mentioned were products found within the forests. The superintendent with the responsibility for the forests was supposed to have knowledge about botany in order to identify and classify trees and plants according to their use. Numerous species of plants and trees were classified and listed in the Arthaśāstra**,** especially for their use as medicines. Those early texts provide rather detailed information about the diverse nature of that time period. Although the Arthaśāstra promoted the protection of fauna and flora for economic gain, it was also concerned about the sustainable use of the environment. Kauṭilya suggested considerable fines for anyone harming or damaging sacred trees or groves. Book three of the Arthaśāstra reveals that profound knowledge of the fragility and resilience of nature was the basis for the state's extraction of natural resources for material gain. Kauṭilya suggested optimal use of resources in a sustainable way to increase the wealth and happiness of the kingdom (McGee 2000).

The king was supposed to manage the natural resources for the benefit of his people, like a well organised household. He should have his forests guarded by soldiers to keep away thieves. One sixth of the products of trees, like fruits, honey, and herbs, belonged to him. The king was also obliged to leave forest patches for the practice of ascetics, for Veda-studies or for sacrifices. He was obligated to appoint people with profound knowledge of trees and plants to manage such forests (Shamasastry 1915).

As Kauṭilya's Arthaśāstra shows, the protection of trees and forests in India in the past was not only based on religious grounds but also a matter of politics. It is probably one of the oldest documents on prudent and sustainable natural resource use and management. In contemporary India one can hardly talk about sustainable resource management since rivers are polluted and forests are eroded due to the pressure on natural resources from an ever-increasing population. However, as the Arthaśāstra indicates, the respect towards nature has deep roots in Indian culture.

4. Material and methods

4.1. Study area

4.1.1. General remarks

South India can be defined in geographical terms and as a distinct cultural region that is bound together by its historical roots, culture and the affiliation to the Dravidian language family. Geographically, South India forms a peninsula that is surrounded by the Arabian Sea on the west, the Bay of Bengal on the east and the Vindhya and Satpura mountains ranges, in the north. The Narmada River that flows westwards along the depression between the Vindhya and Satpura ranges, together with the Mahamadi River, marks the traditional boundary between southern and northern India. The three most important rivers in South India are the Godavari, Krishna, and Cauvery. These rivers build up large deltas and supply water for irrigation along their courses; wherever dams have been built, they contribute significantly to the agricultural prosoperity in the area (Nag and Sengupta 1992).

Robert Caldwell (1814-1891), a Scottish missionary and bishop, was the first to call the family of the South Indian languages Dravidian, and the people who speak it Dravidians, in his studies of the grammar in 1856 (Encyclopaedia Britannica 2009). In the early historical period of the Indo-Aryan people, the Tamil speaking Brahmins developed a different system of social, religious and ritual practices from the Brahmins of the northern regions of India (Aiyangar 1914). While some scientists call the Dravidians the original Indian people, others believe that they had entered the country from the northwest before the Aryans (Sjoberg 1971). It is assumed that the Dravidians were spread all over India, and that through the expansion of the Aryans into the Gangetic plain they have been gradually pushed south. Contact between the Aryans and Dravidians is evident also in the Vedas, where they were named "*dāsas*", and described as dark-skinned, "snub-nosed" people (Sjoberg 1971).

The study area where the material for this thesis was collected is situated in two states of South India, Andhra Pradesh and Tamil Nadu. The data collected from Andhra Pradesh, in 2005, deals with the different aspects of *P. juliflora* concerning its use, distribution, and impact on livelihood. The data acquired from Tamil Nadu, in 2008, consist mainly of information about the perception of sacred trees, tree rituals and the classificatory system of trees.

4.1.2. Andhra Pradesh

The state of Andhra Pradesh was established in 1956 on the basis of language, combining the former Andhra State and Telangana (region of Telugu speaking people), which earlier belonged to the State of Hyderabad. Andhra Pradesh is the fifth largest of the 28 states of India, in terms of population (76 million people) and area. The state is situated in the south of the peninsula and extends over an area of 275,000 sq km, which accounts for 8.4 percent of the entire country (Figure 4). The population density, according to the 2001 census, is 275 people per sq. km.

Geographically, Andhra Pradesh lies between 12º 37' and 19º 54' north latitude and 76º 46' and 84º 46' east longitude. The state consists of 23 districts and 1104 mandals (the administrative level below states and districts), with Anantapur as the largest district. The neighbouring states are Orissa and Chhattisgarh in the north, Maharashtra and Karnataka in the west, and Tamil Nadu in the south.

Figure 4. Administrative map of India showing India's States and Union Territories. (Modified from: Nations online 2009). Circles indicate the research areas.

The physiographic regions of Andhra Pradesh are the coastal plains in the east, which extend from the Bay of Bengal to the mountain ranges, the Eastern Ghats, and the plateau on the west side of the Ghats. The mountains of Eastern Ghats reach the far south, extending from central India and continuing parallel to the east coast. The coastal plain covers almost the entire length of the state and many rivers flow from west to east through the hills onto the plains. The Godavari and the Krishna Rivers form deltas in the central part of the plains that are covered with fertile alluvial soil. Part of the Deccan Plateau forms the landscape to the west of the ranges with average elevations of 500 m. The south of the plateau is situated in the region of Rayalaseema while the northern part forms Telangana. The plateau forms an area with red, sandy soil, a result of erosion. Also black soils cover some parts of the region (Pullaiah and Rani 1999).

Andhra Pradesh is bound on the east by the Bay of Bengal, with a coastline of 974 km. The capital of Andhra Pradesh is Hyderabad, with a population of about 4 million people. The urban population in the state is 20.5 million, which represents a share of 27 percent of the state's total population, living in 264 towns and their surroundings. The rural population of 55 million lives in and around 28,123 villages in an area of 270,000 sq km (SoE-AP 2004). The principal languages of Andhra Pradesh are Telugu and Urdu, the latter mainly spoken by the Muslim population.

The state of Andhra Pradesh can be divided into three regions based on physical, social and economic conditions:

1. Coastal Andhra in the east,
2. Rayalaseema in the south, and
3. Telangana in the west, with Hyderabad as its capital.

The population of Andhra Pradesh has been increasing constantly since the independence of India (by 13, 9 percent up to 2001). Divided into regions, Telangana registers the highest population growth rate of 17.7 percent, followed by Rayalaseema (15.2 percent) and Coastal Andhra (9.9 percent), since the first census in 1951. However, the 2001 census indicates a decrease in the growth rate for the first time after independence (SoE-AP 2004).

Coastal Andhra is regarded as the economically and socially most advanced region of Andhra Pradesh. It has rich agricultural lands due to the existence of the delta fed by the Krishna, Godavari, and Penna Rivers. The prosperity of the region can be attributed to the abundant water supplied by these rivers, which allows intensive irrigation agriculture. Coastal Andhra is known as the granary of South India and a major portion of food and commercial crops are grown there. The region extends to an area of 92,900 square kilometres.

The Telanga region lies on the Deccan plateau to the west of the Eastern Ghats range and is divided into two main regions, the Ghats and peneplains. The Krishna and Godavari Rivers flow through the region from west to east. Most of the area is covered by drylands and agriculture is practised with water supplied from reservoirs/dams, tanks and bore wells. Although agriculture is not as profitable as in the coastal area, the region has developed a well-functioning industry.

The region of Rayalaseema is situated in the semi-arid area in the south of Andhra Pradesh and lacks a major water supply. It is separated from Coastal Andhra by the Eastern Ghats and from Telangana by the low Erramala hills. The area has long been known for droughts and famines. Compared with the other two regions, Rayalaseema is economically and industrially less developed. It is a rocky area with infertile soils and unpredictable rainfall (Government of India 2009; India 2005).

Climate and rainfall

According to its latitudinal location, Andhra Pradesh is situated in the tropical zone, with generally hot and humid tropical monsoons. The southwestern part of the state is classified as hot-steppe with a daily mean temperature of 18º C or less. The climate of all the other regions is tropical-rainy with maximum temperatures in the summer season ranging between 37 and 44º C. Temperatures during the winter season vary between 14 and 19 º C.

Andhra Pradesh receives rainfall chiefly from two monsoons: the main rainy season results from the south-west monsoon, which usually starts in the second week of June and lasts until September. The rains are heavy, especially in the northern parts of the state. The north-east monsoon occurs during October and November and brings most rains to the southern areas. There is a decrease of rainfall from north to south.

The annual rainfall in Coastal Andhra varies between 700 and 1,500 mm. The northern and central areas of the coastal regions receive most of their rain from the north-east monsoon while the southern parts of the coast line obtain only 60 percent of the monsoon rain during the same period. The other parts of Andhra Pradesh receive 60 percent of their annual rain from the south-west monsoon. The driest region is Rayalaseema; it receives only 60 percent of the average annual rainfall with an annual precipitation of 500 mm. Some parts of north-west Rayalaseema receive even less rain. In the Telangana region, the average annual precipitation ranges between 750-1,000 mm, with higher values in the northern parts and the lowest in the southwestern parts (Pullaiah and Rani 1999).

Land, water, and forest resources

Land utilisation in Andhra Pradesh experienced marginal changes between 1960-61 and 1998-99. The cropping intensity of the area increased under irrigation during the 1980s and 1990s. The net area sown has remained constant and varied between 39 and 41 percent of the entire geographical area during the period 1960 to 2001 (Table 4). The under-utilised area under fallow (as a result of year-to-year fluctuations in cropped areas due to rainfall) exceeds eight percent, which is higher than fallow lands on a national level (4 percent). During recent years, increasing degradation of crop lands due to soil and water erosion has been observed in various areas of Andhra Pradesh. Water-related erosion exists in the form of direct or indirect erosion. Floods and surface run off cause direct erosion. Indirect erosion is caused by the inappropriate use of water and results in soil alkalinity and salinity. Industrial effluents pollute rivers, tanks and even the subsurface groundwater. An estimated 3.2 million hectares of land is classified as degraded in one form or another, which accounts for 10 percent of the entire geographical area of Andhra Pradesh. Degradation of cultivable lands extends to 19 percent. An estimated 3.6 million hectares falls under the category of wastelands. Those lands are not necessarily degraded but are not suitable for cultivation (Reddy and Behera 2003).

The degree of land degradation varies across the districts and ranges from three percent in the west Godavari District to almost 50 percent in the Visakhapatnam District. Further, there is indication that the incidence of degradation is higher in less irrigated regions like Rayalaseema and Telangana. The drylands in the region receive less economic support from the state government's public resources, when compared to the well-endowed regions which are selected to supply the country's food requirements and are thus sponsored to increase and improve irrigation (Reddy and Behera 2003).

Table 4. Changes in land utilisation in Andhra Pradesh. (Modified from Reddy and Behera 2003).

Area, mill. ha (%)

	Classification	Time period									
		1960-61		1970-71		1980-81		1990-91		2000-01	
1	Forests	5.97	(22)	6.34	(23)	6.18	(23)	6.27	(23)	6.20	(23)
2	Not available for cultivation	4.11	(15)	4.35	(16)	4.50	(16)	4.44	(16)	4.62	(17)
3	Misc. tree crops & groves	0.29		0.29		0.27		0.26		0.27	
4	Common pool resources	3.52	(13)	3.04	(11)	3.19	(12)	3.01	(11)	2.82	(10)
5	Current fallows	2.23	(8)	2.07	(8)	2.27	(8)	2.60	(9)	2.31	(8)
6	Net area sown	10.7	(39)	11.3	(41)	11	(40)	10	(39)	11.2	(41)
7	Total geographic area	27.4	(100)	27.4	(100)	27.4	(100)	27.4	(100)	27.4	(100)
8	Cropping intensity (in %)	110		112		115		120		123	

Figures in brackets are percentages.

There is a severe scarcity of drinking water and water for irrigation in Andhra Pradesh. In addition, waterlogging causes environmental problems, such as desertification, in fragile areas. On the other hand, large and medium sized irrigation projects are at present underutilized due to mismanagement of the distribution system. As a result, there is an increase in water logging, siltation and poor drainage. The development and construction of well irrigation was neglected in the past and is today entirely left to the private sector. Well irrigation has become the major water resource in agriculture. Thus groundwater irrigation has become the single largest source of irrigation, covering most of the rain-fed regions and more than 60 percent of the total cropped lands. Consequently, there is a significant decline in the watertable observed in the most fragile areas that now suffer from water scarcity and inequitable distribution of water (Reddy 2003).

Existing water harvesting and storage systems, such as tanks and ponds, which have been traditionally maintained by the local people with the help of institutional support, are left without care and are degenerating. It is not only agriculture that suffers from the problems outlined above, but the degeneration of traditional water harvesting systems results in polluted water and a decline of per capita water availability, particularly in the rural areas (Reddy and Behera 2003).

The forest area is estimated at 6.38 million hectares (23 percent) of the geographical area of Andhra Pradesh, which is slightly higher than the national coverage (21 percent). The forest area consists of Reserved Forest (79.2 percent), Protected Forest (19.4 percent) and Unclassified Forest (1.4 percent). The five forest types in Andhra Pradesh are classified as Tropical Dry Deciduous, Tropical Thorn, Tropical Moist Deciduous, Tropical Dry Evergreen, and Littoral and Swamp forests (Pullaiah and Rani 1999; Reddy and Bandhi 2004).

Andhra Pradesh owns four National Parks that occupy an area of 0.33 million hectares and 21 Wildlife Sanctuaries (1.25 million ha). Altogether an area of 1.58 million ha (5.76 percent) of the

entire geographical area is protected. Of the 23 existing Tiger Reserves of India, one is located in Andhra Pradesh (Reddy and Bandhi 2004).

The area under forest cover declined marginally during the 1980s and 1990s when compared to the 1970s. Official estimates indicate that 29,000 hectares of forest land was encroached on by 1994. The major source of forest loss is attributed to the conversion of forest lands to agricultural use, followed by losses to mining. In addition, irrigation projects are regarded as causes for the loss of forests. Along with the quantitative depletion of forests there is a qualitative decline as reflected in forest degradation, which leads to lower revenues generated from forest products (Reddy and Behera 2003).

Agriculture

Agriculture and allied sectors provide employment for about 65 percent of the population of Andhra Pradesh. They are the main income sectors, providing 30 percent of the state's GDP. Out of the total geographical area, 14.6 million hectares are arable land with 10.5 million hectares used in dryland agriculture. The remaining 4.1 million hectares are facilitated with irrigation (SoE-AP 2004). The major crop and staple food is rice, which contributes about 77 percent of the food grain production. The state is also the main producer of tobacco nation-wide. Andhra Pradesh is one of the few states in India that inaugurated the Green Revolution in the 1970s. The growth rate in "Agriculture and Allied Sectors" reached 2.21 percent in the 1980s and increased only marginally in the post-reform period a decade later (2.47 percent), which is slightly below the national rate. Although the growth rate of crop output decreased from 3.4 percent in the 1980s to 2.3 percent in the 1990s, the growth rate in "Agriculture and Allied Sectors" maintained its level during the ten year period.

During the period of 1990-99, the growth rate of GDP from agriculture declined from 4.2 percent annually in the 1980s to 3.7 percent per annum in the 1990s. Compared with agriculture on the national level, Andhra Pradesh experienced significant acceleration in agricultural growth in the first phase of the Green Revolution. One of the reasons for the initial high performance is due to rice cultivation, the main beneficiary of the Green Revolution in the initial phase. Additionally there was a steady growth in all food grain crops, especially pulses and pearl millet. The second phase of the Green Revolution saw stagnation in the growth rate on the state level while on the national level the agricultural output increased. The 1990s brought deceleration in the growth rates of yields of all the important crops, including rice, groundnut, cotton and sugarcane. Although there was a growth in the gross cropped area of 0.6 percent annually, and an increase in cropping intensity from 117 percent in 1988-89 to 123 percent in 1989-99, the output declined during the entire decade (Subrahmanyam and Sekhar 2003).

Despite a significant reduction in crop output, the overall production of the agricultural sectors remained constant. The main reasons for that are attributed to the diversification of agriculture into various enterprises like animal husbandry (dairying, poultry, etc.), which takes a share of 20 percent of the State Domestic Product from agriculture (Rao and Dev 2003). Milk production increased up to 5.7 percent annually with an estimated further growth in demand to approximately six percent annually in the first decade of the 21st century. The increase in dairying has caused a shift from cattle to buffalo for milk production since the mechanisation in the agricultural sector requires less animal power. An increasing demand for mutton has encouraged farmers to increase the population of small ruminants. The specialization in poultry production has significantly increased egg production, which now reaches 20 percent of the total amount of eggs produced in India. The

increased demand for these products is associated with the rise in per capita income, which enables people to spend more money on protein food (Rao and Dev 2003).

In the future, there will be an increased migration from rural to urban areas in Andhra Pradesh. The degrading land and lack of agricultural possibilities, along with increased population, are contributing factors of this trend. Competition among people to make a living will increase in the urban regions. In the rural areas, a smaller amount of farmers need to produce more agricultural products, which might boost food prices.

4.1.3. Tamil Nadu

The State of Tamil Nadu is situated in the southernmost part of the Indian Peninsula. The geographic location of the state is between 8° 5´ and 13° 35´ N. latitude and between 76° 15´ and 80° 20´ E. longitude. The population of Tamil Nadu is 62.4 million, living in an area of 130,000 sq km, which corresponds to a population density of 480 people/sq km. The boundaries of the state are Andhra Pradesh to the north, Karnataka to the west, the Bay of Bengal to the east, and the Indian Ocean to the south. The length of the coastline is 1076 km. More than 90 percent of the population are Hindus with small minorities of Muslims (3.5 million) and Christians (3.8 million). Also a small community of Jains live in and around the cities of Arcot and Chennai. Thirty-five million people live in rural areas and around 27 million (44 percent) live in urban regions. This is the highest urbanisation rate in India. Out of the whole population, 73 percent are literate which means that 22 million are illiterate. The capital of Tamil Nadu is Chennai which is India's fourth-largest city, with a population of 6.4 million (Census 2001).

The natural division of the state occurs between the flat areas situated alongside the east coast and the mountainous regions in the north and west (Figure 5). The driest parts of the state are found in the arid lowlands which surround the historical cities of Madurai and Ramanathapuram. The highest mountain in South India is Anai Peak (2,695 m) in the Anaimalai Hills. The major rivers are the Cauveri (Kaveri), the Palar, the Ponnaiyar, and the Vaigai (Encyclopaedia Britannica 2009).

Climate and rainfall

The climate of Tamil Nadu is specified as inland/ equatorial/ tropical and coastal-equatorial/ maritime along the eastern coastline. There are tracts of sun-burned, sandy drylands in the southern regions and cool areas in regions of the Nilgiris and the Kodaikanal hills. During the hottest months in May-June the temperatures in Chennai exceed 38 ºC while in the cool period in December-January the average temperatures drop to 21º C. Depending on the southwest and northeast monsoon, the average annual precipitation ranges between 630-1,900 mm. The larger amount of rainfall comes during the north-east monsoon between October and December. The most precipitation is recorded in the mountainous and hilly regions in the western part of the state and the lowest rainfall is recorded in the lower southern and south-eastern regions (Government of India 2009, Encyclopaedia Britannica 2009).

Ootacamund (Ooty), a hill station in the Nilgiris Mountains (literally "Blue Mountains in Indo-Aryan languages), was explored by the British in the early 18th century. It is also called the "Queen of Hill Stations". The Niligris are used for eucalypt plantations in afforestation projects from which the oil is extracted for the pharmaceutical industry. The Western and Eastern Ghats meet in Tamil

Nadu. The Cauvery River flows across Tamil Nadu dividing the State into two halves. It is the only perennial river that is fed by both monsoons. Most of the lakes are used for irrigation and small ponds (*ooruni*) supply drinking water to the villages (Chettiar 1973).

Land, water and forestry resources

The forest area of Tamil Nadu constitutes 22,877 km^2 (17.6 percent) of the geographic area, including 2,440 km^2 of dense forests, 9,567 km^2 of moderately dense forests and 10,636 km^2 of open forest. There are eight wildlife sanctuaries, twelve bird sanctuaries, five National Parks, four Elephant Reserves, three Tiger Reserves and three Biosphere Reserves in the state. There is also a game sanctuary at Mudumalai. The aim of the Tamil Nadu Forest Department is to convert 10 percent of the landmass into Protected Areas (PA), according to the National Wildlife Action Plan 2002-2016 (Tamil Nadu Forest Department 2009).

Along the coastline of the state, 700 ha of mangrove plantations and 2000 ha of shelterbelts were raised in 2005-06 to protect the fragile ecosystem from sea erosion and devastation due to natural disasters like the tsunami in 2004. The implementation of the afforestation program has increased the productivity of the forests and the restoration of degraded forests. The main revenue from forestry comes from the sale of timber and other forest products, like pulpwood, sandalwood, or Non Timber Forest Products (NTFPs), and amounted to almost 1.5 billion Rupees in 2004-05 (Government of India/a 2009).

During the Triennium Ending (T.E.) 1979-80, the net area sown in agriculture extended to 6.3 million ha, which accounted for about 48 percent of the overall geographic area. In T.E. 2005-06, the net sown area declined to 38.5 percent (Table 5), which probably reflects the increase in other fallow lands and an increase in the conversion of agricultural lands into other usages, like the extension of urban areas.

The loss of agricultural lands increased during the reference period from 12.9 percent to 16.3 percent. The main reasons for the conversion of agricultural lands into other fallow lands are the increasing urbanisation and a lack of adequate water availability. The monsoon rains have failed to supply sufficient rains which make rainfed agriculture a difficult undertaking. Other fallow lands include land that has been taken out of cultivation for a period of one to five years. Also the irrigation water supply from the Cauvery River has become uncertain and the depletion of ground water causes difficulties in bore well and tank irrigation. These lands may also be covered with shrubs and thickets which are not usable for agriculture.

Other cultivable land that does not fall under the category of net area sown are lands cultivated with tree crops like casuarina, teak, bamboo, or other woody plants. The area amounts to 270,000 ha, roughly 2.1 percent of the entire geographical area. The estimated forest area has remained steady and saw only a slight increase of less than one percent, to 16.3 percent (2.1 million ha), in the last 25 years. All grazing lands, including those within the forested area and village common grazing lands, fall under the category of permanent pastures and other grazing lands and amount to 0.8 percent of the geographical area of the state. The area of barren and uncultivable land extends to half a million hectares, which represents 3.9 percent of the geographical area of Tamil Nadu. The lands under this category are mountains, deserts, hills, etc. (Government of India/b 2009).

Table 5. Changes of land use pattern in Tamil Nadu. Modified table. (Government of Tamil Nadu 2009).

Area, mill. ha (%)

	Classification	Time period					
		1979-80		1999-00		2005-06	
1	Forests*	2.03	(15)	2.14	(16)	2.12	(16)
2	Barren and uncultivable land	0.61	(5)	0.48	(4)	0.51	(4)
3	Land put to non-agricultural uses	1.68	(13)	1.97	(15)	2.13	(16)
4	Cultivable waste	0.35	(3)	0.35	(3)	0.37	(3)
5	Permanent pastures and other grazing lands	0.17	(1)	0.12	(1)	0.11	(1)
6	Land under miscellaneous tree crops and groves not included in the net area sown	0.20	(2)	0.24	(2)	0.28	(2)
7	Current fallows	1.26	(10)	1.00	(8)	0.8	(6)
8	Other fallow lands	0.46	(3)	1.14	(9)	1.70	(13)
9	Net area sown	6.26	(48)	5.56	(42)	5.01	(39)
10	Total geographical area	13.02	(100)	12.99	(100)	13.04	(100)

* Forest area in 2009: 22,877 km², 17.59 percent of the geographical area of Tamil Nadu (of total India forest area: 2.95 percent).

Agriculture

Agriculture contributes to the major share of the economy in Tamil Nadu. It provides jobs and livelihood for 56 percent of the population and supplies raw-materials to agro-based industries. An inventory in 2001-2002 revealed a total area of 6.23 million hectares of agricultural land. Approximately 56 percent of the agricultural land is irrigated while the remaining 44 percent depends on rainfed farming. Agricultural revenues have increased from the mid-20th century onwards due to multiple cropping and the application of chemical fertilizers. During the same period, the state has exceeded the production and application of bio-fertilizers. In the state budget, the agricultural sector contributes to 13 percent of the total income. The major crops include rice (annual average yield of eight million tons), millet and other cereals. Among the commercial crops (cash crops) are sugarcane, coconut, cotton, sunflower, cashew, chilly and groundnut. The total area under cultivation depends on the amount and quantity of precipitation. The area used for the production of paddy has increased from 1.9 million ha in 2003-04 to 2.1 million ha in 2005-06. Due to the increase in paddy fields, the annual paddy production also increased from 3.2 million tons in the 2003-04 season to 5.2 million tons in 2005-06, which indicates a yield rate of 2500 kg/ ha at its best. There are also a number of plantations that grow tea, coffee, rubber and cardamom (Government of India/a 2009; India 2005).

Raising livestock is common among farmers, and cows are used primarily as draught animals and for milk and other products in the dairy industry. Other important farm animals are poultry, sheep and goats. The total livestock population in the state indicated a slight increase (1.01 percent) in 1997 when compared to the previous 1994 census. While the number of cattle and buffaloes has witnessed a steady decline, the goat population has increased. Poultry is on the increase as well and

accounts for 17.7 percent of the poultry in India, ranking it second highest in the country (Government of India/a 2009).

Similar to Andhra Pradesh, also Tamil Nadu is facing an increasing migration from rural areas to urban regions. Especially Cennai, the capital of the state, is modernising on high speed and attracting investors from all over the world. This creates a need for people that built up the growing metropolis. The salaries for workers in the building industry are relatively high compared to those in rural areas. In addition, increasing environmental hazards and lack of agricultural lands speeds up the annual migration.

4.2. Research methodology

4.2.1. General remarks

The present study represents multidisciplinary research where approaches from natural and social sciences are combined. It includes concepts and methods from forestry, anthropology, ecological and economic sciences and a combination of quantitative and qualitative methods. Qualitative research refers to studies that include qualitative analysis that attempts to understand phenomena from the participant's perspective. An important characteristic of qualitative research is that the researcher follows an inductive process, which means that data are gathered to build concepts, hypotheses or theories rather than to deductively test hypotheses. Qualitative research builds an analysis from observations and intuitive understanding of the information gathered in the field (Silverman 2000; Merriam 2002). The outcome of a qualitative inquiry has a rich descriptive character using words and pictures rather than numbers (Merriam 2002).

According to Bryman (1988), participant observation is probably the method of data collection which is most closely associated with qualitative research. The favourite technique in this method is unstructured interviewing in which the interviewees are encouraged to offer their own opinions or definitions of particular activities. The use of semi-structured interviews has as its general goal the revelation of existing knowledge, expressed in the form of answers, that become accessible to interpretation. Semi-structured interviews allow a person to answer on their own terms, which is not the case with standardized interviews (Flick 1998).

4.2.2. Fieldwork in the states of Andhra Pradesh and Tamil Nadu

This study concentrates on trees in general, and prosopis in particular, and their impact on the livelihoods of people in South India. The data collection was accomplished during two field trips:

1. The core data were gathered in the South Indian state of Andhra Pradesh between May and August 2005.

2. Complementary data, consisting of information concerning the cultural aspects of the study were collected in the state of Tamil Nadu during December and January 2008-2009.

In both states there are arid and semi-arid areas which are invaded by prosopis to various degrees, depending on climatic factors. The main data that deal with the direct influence of prosopis on

livelihood were collected in Andhra Pradesh. Collecting additional data in Tamil Nadu was determined by the fact that the cultural heritage of tree worship is still most alive in contemporary South India. The climatic conditions prevailing in both states are very similar and the role of prosopis in livelihood management is rather similar in both states. However, tree worship is more predominant in Tamil Nadu, with a high occurrence of tree species classified as sacred, like the bodhi (*Ficus religiosa*) and the banyan tree (*Ficus benghalensis*). There is still a high diversity in the number of local deities; this practice has its roots in Dravidian history even before the appearance of the Aryans (Nugteren 2005).

Choice of data collection methods

In this study, participant observation was used to collect the field data. The technique is based on asking questions, listening, watching and keeping detailed field notes. The basic method used to collect primary field data was through semi-structured interviews with open-ended questions asked of individual people and groups, which Rubin and Rubin (2005) describe as "responsive interviewing". The model of responsive interviewing relies on the interpretive constructionist philosophy. The goal of the research in responsive interviewing is to generate a depth of understanding by using a research design that remains flexible throughout the entire study (Rubin and Rubin 2005).

The communicative competence of the researcher is the main tool in collecting data. The successful adoption of an appropriate role by the researcher decides which material he gains access to and what is excluded from him (Flick 1998). However, despite the communicative capabilities of the researcher, the research assistants or interpreters and their skills in creating a natural and easy atmosphere are an important supportive factor during the interaction with the local people.

Observations made of the daily activities of local people and of the environment added complementary information to the data gained through interviews. In Andhra Pradesh, the surveys of the biophysical environment concentrated, especially, on the occurrence of the prosopis tree. The observations of the daily activities of the local people focused on the way they sustain their livelihoods, for instance by collecting firewood, cutting prosopis wood or being involved in agricultural activities. During the interviews, all kinds of observations that would add additional useful information to the research were written down immediately. Those observations could deal with something peculiar in the environment or with the behaviour of the local people in connection with the interview situation. In Tamil Nadu, specific attention was given to the observation of various rituals connected with trees. Every day after the fieldwork, the interviews and observations were once more discussed between the researcher and the assistant before they were written down in detail.

In participant observation, ethical norms are guidelines for behaviour in particular situations. Researchers have an obligation to honour and not deceive the interviewees by, for instance, promising any benefits that will come to them from the research that can not be delivered (Jorgensen 1989). In this spirit, it was made certain through the assistants that the interviewees were informed about the nature of the research and the background of the researcher before the enquiry started. The assistant also ensured the people that the information given during the interview would be handled with confidence and would by no means have any negative influence on their daily life. With the permission of the people, pictures were taken showing their lives and activities. Any photographic material that added additional value and information to the research was part of the data collection.

The questionnaire with open-ended questions for the informants was prepared and formulated beforehand, keeping the general research questions in mind. After testing the questionnaire in the field, the questions were revised and modified according to the experience gained during the interviews. The questions were meant to be a guideline but the design remained flexible in order to adapt to the actual experience during the entire field period.

Data collection

The fieldwork in Andhra Pradesh was carried out in 2005 during the period of extreme drought and heat in May and the peak of the monsoon during August. The first data collection covered almost the entire area of Andhra Pradesh. The three regions, the eastern Coastal Andhra, western Telangana, and southern Rayalaseema, vary in climatic conditions and soil qualities. This influences the mode and intensity of farming (irrigated or rainfed) as well as the composition of crops. Climate is a major factor in deciding the occurrence and density of the prosopis trees. The data collection took place in the rural and urban areas of the regions.

The state of Andhra Pradesh is divided into 23 districts out of which 22 were investigated during the research. The district of Adilabad was left out from the inquiry because of ongoing violent escalations between Maoist groups and police in the northern regions of the district. However, since the climatic conditions and the soil type and structure are similar to those of the neighbouring district of the Telangana region, the absence of the Adilabad District has no effect on the results of the study.

The individual interviews included 144 persons, each representing one household (Table 6). The sampling of the interviewees was done in order to receive information that enabled the researcher to answer the research questions. Maxwell (1996) recommends using purposeful sampling in qualitative research which does not require as large a number of samples as reqired in random sampling. In this study, sampling was realized and guided by the criteria that the person to be interviewed should have some kind of connection to the prosopis tree. Such connection could be a prosopis tree in the house yard, a prosopis living fence on a crop field, any labour activity handling prosopis, like cutting prosopis trees, or simply the use of prosopis as firewood. With the growing insight into the lives of the people that was gained through the observance of their daily activities, it was possible to formulate the questions in an appropriate way so as to gain information that could help to answer the research questions.

Table 6. Interviewees by gender in Andhra Pradesh.

Individual interviews	Men	Women	Total
Coastal Andhra	81	19	100
Telangana	25	1	26
Rayalaseema	17	1	18
Total	123	21	144

In addition to the individual interviews, group interviews were conducted with two to seven interviewees at a time. Those groups consisted of only men, only women or mixed groups (Table 7). The groups were not selected according to specific criteria. In many cases they can be called natural groups that formed themselves for practical reasons, for example, farmers in the crop fields or groups of people gathering near a tea shop or under the shade of a tree. The questions for the group interviews were formulated differently from those of the individual interviews and were influenced by the composition of the group and by the way people were related to the research problem.

Table 7. Composition of group interviews.

Group interviews	Men	Women	Men & Women	Total
Coastal Andhra	7	1	4	12
Telangana	5	2	2	9
Rayalaseema	5	1	2	8
Total	17	4	8	29

A third group of interviewees consisted of so-called key informants, people with specific knowledge related to the research questions. Those key informants were officials from the National Forest Department or scientists in the field of plant science or environmental sciences (Table 8). The questions to key informants were thematic, tailored according to the field of competence of the person. Those interviews were unstructured and took on more of a conversational character. The information provided by the key informants can be classified as expert information, which the researcher would not have had access to through other means.

Table 8. Key informants with access to expert information.

Interviews with key informants	Frequency
Forest Department officials	3
Village head (surpanch)	3
University staff	3
Industrial plants management	5
Total	**14**

The data collection was supported by two assistants who translated the questions and answers from English into the local language of Telugu and back into English. During the first month of the fieldwork, Dr. Prasad acted as a guide and interpreter. As Acting Professor in Plant Biology, his guidance in the field concerning the problematic of the prosopis tree, as well as his background knowledge about social and cultural issues concerning the people of Andhra Pradesh and India more generally, was crucial for a deeper understanding during the research. The second period of

field data collection was realised with the help of Mr. Jayaram Kottapalli, a doctoral student of plant biology who acted as an interpreter.

Among the 144 individual interviews, 7 percent (six households) were non-Hindus (Christians or Muslims). The majority of the interviewees belonged to the Scheduled or Tribal Castes (SC, ST) followed by the Backward Castes (BC). Only 14 percent of the Hindus who responded to the question of caste belonged to the Forward Castes (FC) (Figure 5).

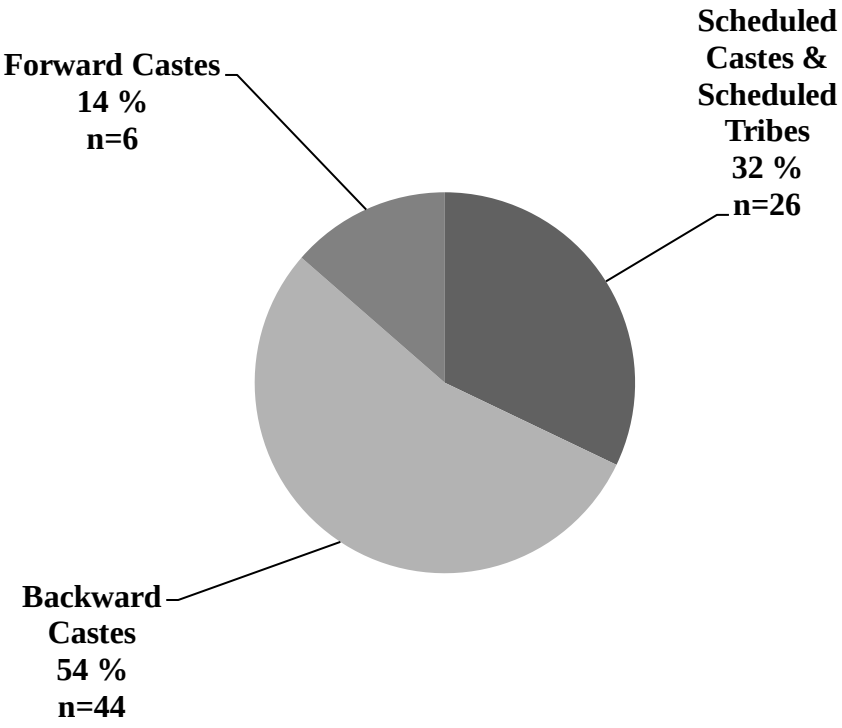

Figure 5. Stratification of Hindu interviewees into castes.

The role of caste was an influencing factor in the interview situation. Different castes usually keep distance to each other in daily affairs. The affiliation of Dr. Prasad, a Brahmin belonging to the Forward Castes, and Mr. Kottapalli, affiliated with the Scheduled Castes, created certain tension among the interviewees when they acted as interpreters during the interviews. Although it was not mentioned to which caste the interpreters belonged, people estimated quite accurately the caste affiliation of the person with whom they were in contact. People recognise the caste of another person by merely looking at their features or colour. The names of people also reveal their caste and even the area of their origin.

Age was also a factor that affected the interview situation. Dr. Prasad was over fifty while Mr. Kottapalli was in his mid-twenties during the time of the fieldwork. In India, the behaviour towards older people is very respectful, which caused additional tension during the interview situation where

Dr. Prasad was acting as an interpreter and the interviewee was younger. The interview situations in which Mr. Kottapalli acted as an interpreter were mostly conducted in an easy atmosphere that made the interviewees talkative and eager to talk freely about their lives and the research.

During the interviews where Dr. Prasad was acting as an interpreter, the atmosphere among interviewees from the lower castes, like BC, SC, and ST, was often rather tense. Although not mentioning the social background, people intuitively recognised his higher social status, which sometimes made them feel uneasy. Mr. Kottapalli's presence among interviewees from the SC and TC often created an easy and relaxed atmosphere during the interviews. Often it was felt that people were happy that someone of their own caste was acting as a mediator. In general, it seemed that people were happy to talk to someone from outside about their lives and opinions. In a few cases, where the interviewees were members of higher castes than the interpreter, the talks were held outside the house in a nearby premise or in the yard.

However, caste is such a sensitive issue in India that problematic situations could not be avoided. During an interview with a Brahmin farmer and his wife, this author called a shepherd, grazing his sheep on the fields behind the farm, to come and join us as an interviewee. Although he obeyed the request, everyone suddenly seemed to feel very uncomfortable. After sitting quietly for a few minutes on a chair, the shepherd excused himself and left to go back to his livestock. After the interview, when reflecting on the situation, Mr. Kottapalli explained the embarrassment the situation had caused to everyone around the table.

From the beginning and without any words, it was clear to everybody, except the researcher, that the shepherd belonged to the Scheduled Caste. In entering the yard of the Brahmin farmer, and even sitting together with them around the same table, he broke the law of purity, which is a serious offence. Although he was aware of the situation, he probably took the invitation of a white skinned person from the West as compulsory and so violated the invisible border that separates people from different castes. As Mr Kottapalli explained, the farmers probably had to perform purification rites to clean the space that had been violated through the presence of someone who is a member of the Scheduled Caste.

Data collection in Tamil Nadu

An additional collection of data was carried out in villages in the near proximity of Kumbakonam, a town of 60,000 inhabitants situated in the fertile plain of the Tanjore District. For the Hindus, it is an important place of pilgrimage to one of their holiest shrines in South India. The data collection was realized with the assistance of Mr. Rajasekar Ramdas, who functioned as an assistant and interpreter, translating the Tamil language into English and the questions from English into Tamil.

The data were collected from 16 group interviews and six individual interviews with men. The choice of using group interviews as the major source of data depended on the fact that the desired information is common knowledge. In the groups, the discussions were enriched by comments from all the members involved. The groups consisted of two to seven members, male and female, covering all ages. Often, the questioning was addressed to one person while others added facts and stories, which were in turn questioned or confirmed by others joining the discussions. Although the concept of the interview and the questions were pre-formulated, the final result resembled more a discussion about subjects related to the research questions.

The choice of individual interviews was determined by the fact that those people happened to be at or near places of interest, like sacred shrines and temples. The choice of the interviewees was determined by the place or activity of the person. The main attention focused on people involved in activities connected with trees or those who had any connection to sacred trees or temples. The focus was on cultural and religious practices, with the aim of understanding the behaviour and value system of Hindus in connection with their environment.

Both periods of data collection followed a similar pattern. After the daily fieldwork, the researcher discussed the events of the day with his assistant in order to develop strategies that would create a spirit of mutual confidence between the researcher, the assistant and the interviewees. The intention was to interact with the people under the ordinary conditions of their daily life. As the fieldwork proceded, the strategy of interviewing developed. The experience showed that a more easy-going conversation was created when the interviewees were not immediately asked personal questions like name, caste or household related matters. Instead, the researcher started the conversation by engaging verbally in the activities the person was doing by asking questions related to the situation. Only after explaining the purpose of the research and the interviews, and after the request was accepted, the questions turned to become more specific and research orientated.

In addition to the field material described above, other sources of data consisted of various scientific publications (e.g. The Indian Forester), project documentations, statistical data from different institutions (e.g. climatic or agricultural data), digital geographic maps with soil classifications, as well as newspaper articles from the leading local press.

4.3. Evaluation of the data collection method

4.3.1. Reliability of the collected material

According to Bryman (1988), one of the issues of concern in qualitative research is whether researchers are able to provide accounts from the perspective of those whom they study, and how one can evaluate the validity of the interpretations of those perspectives. Silverman (2001) suggests that reliability can be addressed by using standardized methods to write field notes or by tape-recording with careful transcriptions. In this research, no tape-recording was used, but there was a standardized method of conducting the interviews and writing up the field notes. A basic set of questions was asked during the individual interviews in order to enable the researcher to cross-check the answers of the respondents. However, the unstructured interview was predominant and often depended on the willingness and knowledge of the interviewees.

Alan Bryman (2001) points out that in qualitative research, replication, or more specifically replicability, is a difficult undertaking. Probably it would be difficult to get exactly the same results when replicating this study. However, transparency and an exact description of the research process, including the way the material was collected, aims to make this research as reliable as possible.

The data collected from group interviews enabled the researcher to get precise information about quantitative values, which could be discussed and cross-checked during the discussions. Questions about yields of different crops or observations about the invasion of prosopis were discussed among the interviewees and often resulted in more accurate information than individuals would have been able to provide.

One of the important issues of concern in conducting interviews arises when the interviewer does not speak the same language as the interviewees, as is the case in this study. Since language is a central part of the qualitative method, it is obvious that the interpreter plays an important role in presenting and translating the questions and answers during the interview. It is possible that some of the information that might have been important was missed by the researcher because the vocabulary and different ways to express things may vary substantially between different languages. In this research, it was fortunate and important to have two interpreters who were familiar with the research problem due to their field of expertise. Both interpreters had an academic background and were familiar with the requirements of academic research. Mr. Kottipalli, the interpreter who assisted during the major part of the data collection, had experience from similar work during his studies. The task of the interpreters was not only to present and translate the questions of the interviews but also to guide the researcher through sensitive cultural issues. Both interpreters were an important help in identifying key informants and in assisting communications with local officials. In addition, it depended on the skills of the interpreters to introduce the researcher and the research subject to the interviewees in order to awaken interest, trust and willingness to participate in the interviews.

4.4. Analysis of the collected research data

Although analysis of the collected material continued during the whole period of the fieldwork, an in-depth analysis was undertaken after all the data were collected. The main tool used in interpreting the data was content analysis, a method used in the social sciences as described by Flick (1998) and Mayrink (1990). In addition, the method of coding as described by Neuman (1997) was a useful tool to get the information organised and to find the essence of the accumulated data (Figure 6).

The first step was to write down each interview on a separate sheet and code it according to the basic information about age, sex, caste and occupation. The next step was to categorize the information from individual semi-structured interviews according to different themes related to the research questions and label them with the corresponding codes given to the basic information sheets. The categories were not determined beforehand but were the result of the information gained in the interviewes. Through further analysis of the categorized information, new schemes emerged that were again coded into new categories, until all the data could be easily managed and interpreted.

The group interviews and the interviews of key informants, like forest officials and scientists, were analysed separately from the individual interviews. The method that was used to analyse those interviews was similar to the one described above. The information was thematiced and categorised, using the same themes and key words as was done in the individual interviews.

In the final analysis, all the different outcomes from the interviews and the documented material were combined and interpreted with the perspective of providing answers to the research questions. The presentation of the results has a qualitative descriptive character, which is supported by a quantitative summary of the empirical data. With the help of SPSS software, the coded categories were quantified and summarized in tables to give the reader a more profound insight into the research and to illustrate the analysis.

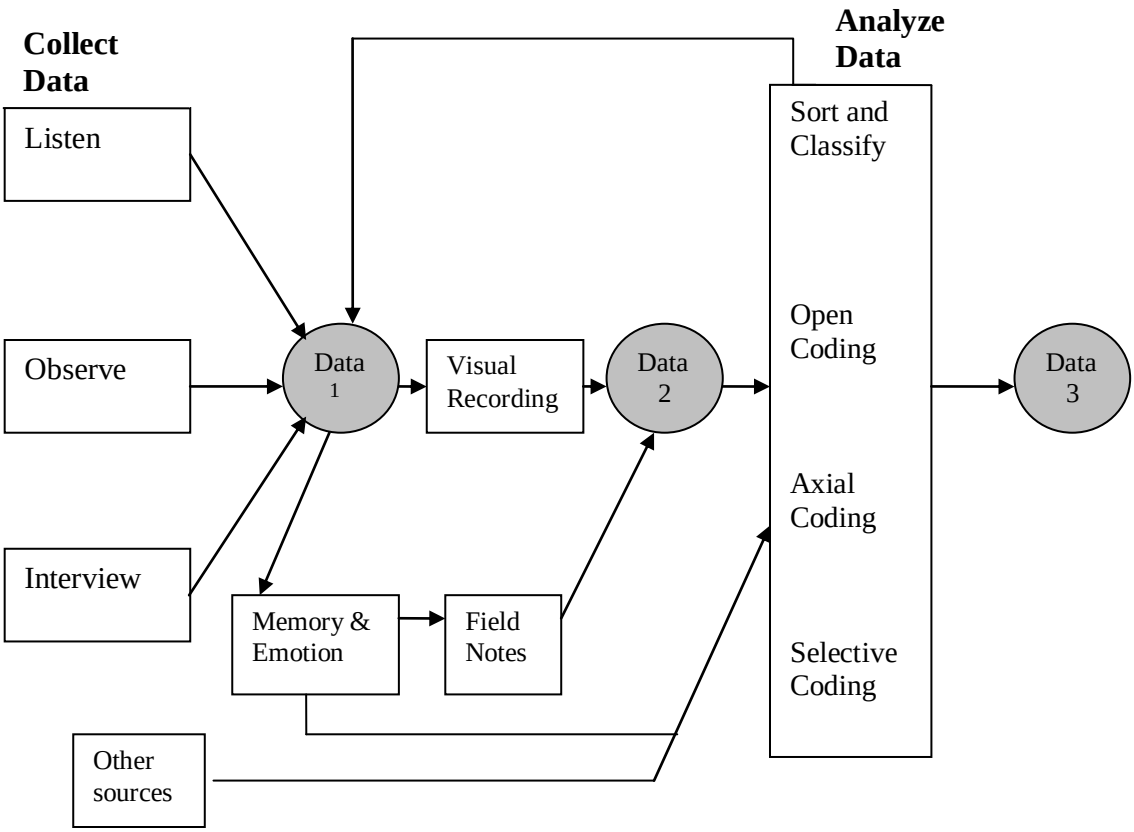

Figure 6. Data collection and analysis in field research (modified from Neuman 1997).

5. Results

5.1. Household livelihoods in Andhra Pradesh

5.1.1. Rural villages in Andhra Pradesh

The villages in many parts of Andhra Pradesh share similar features. By describing the characteristics of the village of Baruva in detail, it is possible to get an idea of what all the villages look like and how they function. It is very common that at both entrances of the village along the main road, or at central places like the vegetable market, there is a huge fig tree, either a bodhi tree or a banyan tree. Under those trees, the people gather during the time of the hot midday sun or in the evenings to talk and gossip with each other. Those fig trees are also planted close to the Hindu temples, which are present in almost every village. Beside the temple for the local deity, there are also temples for various other Hindu deities. Another outstanding common characteristic in rural villages is the way the streets are inhabited according to caste and are kept strictly separate from each other (Figure 7). Most of the villages have similar street patterns as Baruva village.

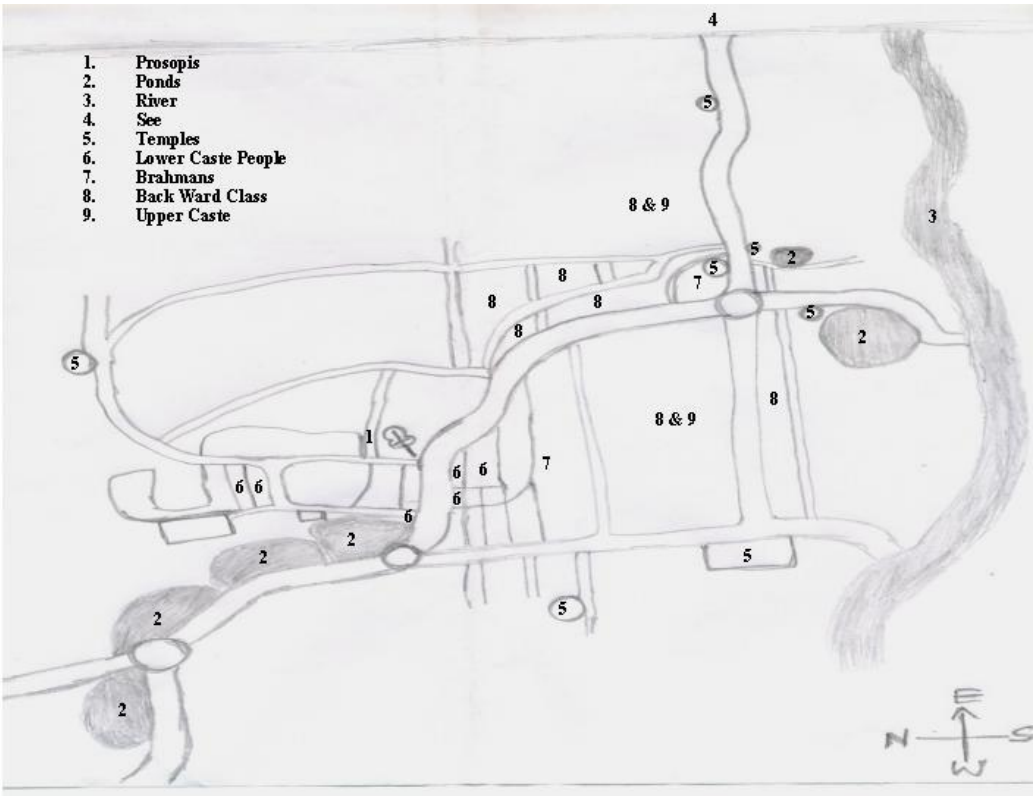

Figure 7. Village map of Baruva in Coastal Andhra Pradesh (Map: Jayaram Kottapalli). [4. See stands for Sea].

As in many villages in Coastal Andhra Pradesh, the population of Baruva is divided into different castes. The majority is formed by the Backward Castes (80 percent) followed by the Scheduled

Castes (15 percent) and the Forward Castes are represented by approximately 5 percent of the inhabitants.

The Brahmins (members of FC) generally reside beside a temple and away from lower caste people. Each street owns its own well for the purpose of washing and fetching drinking water. Tap water may be provided in the areas of the higher caste population but otherwise bore wells fulfil the same purpose in the quarters of the low caste people. These bore wells are used only by people of the same caste in order to keep the law of purity.

Baruva village has approximately 13,000 inhabitants. The rural local village councils are called *panchayats* and the villagers elect the *panchayat* members, including their chairperson, for a six-year period. One of the responsibilities of the chairperson and the committee is to organise funds from the state government to establish and administer education, sanitation, drinking water, and a viable infrastructure. According to the chairperson of the Baruva *panchayat*, the village has undergone many positive changes during recent years. One of the most pressing issues in Baruva, as well as in many other villages, is the rate of unemployment. Throughout the agricultural season, most of the workforce is employed but during the summer months from March until July it is difficult to find work. The positive developments are the school system and the improvement in hygienic matters.

Baruva has five government schools until the 5^{th} class, one school till the 10^{th} class and two junior colleges; it is possible to graduate from one of these with a BA or BCOM. The administration is now applying to get a college, which enables students to continue their education to the BSc. Baruva achieved major improvements in hygienic matters and is organising periodic campaigns to clean the ditches with chlorine. This is done as a prophylaxis in order to prevent the spread of epidemics, from which the village had suffered during the monsoon seasons of the previous years. Another positive feature of the village is the existence of a hospital with a capacity of 30 beds. However, the hospital employs only one doctor with two positions remaining empty. Because the education to become a doctor takes place in bigger towns in Andhra Pradesh and India in general, it is difficult to get doctors to small places in remote areas.

As to education and health service facilities, Baruva is more advanced than many similar sized villages in Andhra Pradesh. The reason for the positive development in Baruva was attributed to the active political work and influence of Kottapalli Narasayya, a member of the state assembly during 1970 – 1984. He grew up in the village and being a member of the SC, he fought for equality in caste matters and for education to be available for all villagers regardless of caste or wealth.

The president of the *panchayat*, the *sarpanch*, stated in the interview that the general basic health of the villagers is good, and there is also a sufficient supply of clean tap water. Since members of the criminal organization of the Naxalet movement were driven out of the area during the 1970s, there have been no reported severe cases of criminal activities in Baruva. Quarrels between villagers that need to be settled are solved by a committee of village elders.

Throughout the village, there are several tree species planted deliberately, of which the neem tree is the most common one. According to the *sarpanch*, the environment in the area around Baruva has become degraded, which he thinks was a result of the periods of drought during the last few years. Economically, the village is better off than during the decades before and also the infrastructure has improved now, with better roads and sufficient water supplies. Domestic electricity is available for most of the households, but there are frequent power cuts, providing electric current for about 10 hours daily. There are several ponds at the edges of the Baruva village (see Figure 7), which are

used for watering and washing livestock or for laundry purposes. Almost every pond is densely invaded with prosopis, which makes it difficult for people and livestock to move there.

5.1.2. Rural households and human capital

In order to get a holistic picture of the way households in Andhra Pradesh maintain their livelihood needs, it is appropriate to discuss the variety of resources available for their production processes. To supply a family, the most important resource is human capital, chiefly labour. Farmers who own land usually form family enterprises, with all family members involved in agricultural activities. During the cropping season, there is a need for additional labour input from outside in order to make agriculture a profitable undertaking. Among the interviewees, almost every household was living in their own house. Those homes could be inherited, bought or subsidised by the government for families with low income. Natural capital available for the households is bound to natural resources and includes land for crops and livestock production, irrigation facilities, and prosopis, the basic resource for fuelwood.

According to the survey, households in Andhra Pradesh are comprised of an average of 4.0 members. The birth rate averages 2.9 children per family. The majority of the higher castes or Forward Castes (FC), and the Backward Castes (BC), are involved in farming while the Scheduled Castes (SC) and the Scheduled Tribes (ST) contribute the main bulk of the labour force (Table 9).

Table 9. Distribution of professions among the different castes.

Caste	Profession	N*	%
SC, ST	Farmer	6	23
	Labourer	11	43
	Herder	4	15
	Other	5	19
	Total	26	100
BC	Farmer	19	43
	Labourer	11	25
	Herder	2	5
	Other	12	27
	Total	44	100
FC	Farmer	8	73
	Labourer	1	9
	Other	2	18
	Total	11	100

N*: Number of respondents.

For the landless people in the semi-arid areas of Andhra Pradesh, labour is the main resource for maintaining their livelihood. Most of the work is available in the agricultural sector with private farmers as employers during the cropping season that starts with the onset of the monsoon. This is

also the time of the highest demand for labour, with the peak starting with the preparation of the fields through ploughing, followed by sowing of the crop seeds. The definite peak of the season occurs with the onset of the harvest. When agriculture is practised for subsistence needs, the family labour input is often sufficient to manage all the necessary work, from preparation of the crop fields to the storing of the harvest.

Just before the arrival of the monsoon, the fields need to be tilled, which opens up work possibilities for households owning bullocks or male buffaloes. The salary for six hours ploughing is 100 Rs, with the precondition that the working animal is provided by the labourer. The work is exhausting and is done only by male labourers. After ploughing, fertilizers need to be applied before sowing can start. The need for weeding appears during the whole cultivation process in different periods and employs mainly females and child labourers. The end of the season occurs when the crops are harvested and prepared for marketing or stored for subsistence consumption. During times of high demand for agricultural labour, the wages are distinctively higher than during the less intense season. Box 1 gives an example of the seasonal salaries of agricultural employees, both men and women.

From the time after the harvest until the beginning of the new agricultural season, there is no need for farmers to employ labour and even landowners are looking for employment and business outside the agricultural sector. The time when the last harvest of the season is brought in depends on the crop variety and the mode of farming. The rain-fed farming season may end in February but irrigation makes cropping possible until April, the beginning of the hottest season. Working possibilities outside the agricultural sector, like in the building sector or handling and transportation of goods, or anything else that requires physical input, are rare and competition for those places is tough. Labourers reported that over the whole year, the average employment is 20 days per month.

Landowners and farmers often employ labour also outside the agricultural season to cut and collect prosopis wood, which they sell to industrial plants and charcoal producers. Labourers might also rent land to cut, sell and use prosopis themselves, if the trees grow on private land. However, everybody has the right to make use of prosopis on government wasteland where the tree grows in high density.

Box 1. Labourer salaries in agriculture.

Mr. P. Suryanarayana cultivates one acre of land where he grows bananas, chilly, finger millet and coconuts on 80 cents (100 cents equals one acre) and rice on 20 cents of the inherited farmland. During the peak of the harvest he needs to employ 6 to 10 workers from outside for a period of 10 days. The salaries during the peak season vary between 80 and 100 Rs for men per day and about 40 to 50 Rs for women per day. In times when labour is abundantly available, the salaries drop and adjust between 50 and 70 Rs for men per day and 20 to 30 Rs for women per day, depending on the agreement with the farmer. When asked why the wages for women are generally lower than those for men, the landlord replied that the difference depends on the heavier physical work input of men compared to women.

5.1.3. Employment possibilities outside the agricultural sector

When asked about the employment possibilities in the villages, villagers gave priority to the number of government jobs that are occupied by the villagers. It became obvious that to be employed by the Indian government is one of the most desirable occupations. Those jobs are rare and available only through the reservation policy for people from the lower castes, like SC, ST and BC. The reservation policy has been implemented since India's independence and guarantees a certain amount of state jobs to members of the underprivileged castes. To be employed as a bus driver or ticket collector means having a secure income until the age of retirement, followed by a monthly government pension. A senior bus ticket collector or bus driver may earn 10,000 to 15,000 Rs per month, depending on the years in service. Employment as a teacher in a government school implies a lot of benefits besides the regular salary, which is on average 15,000 Rs per month, such as occasional presents in the form of fruits, rice, or cereal from the parents of the pupils. It is also a respected position in the community and the teacher is often consulted in social decision making.

As a result, among students it is desired to pass the annual examination for the Indian civil service. The competition for those jobs is very tough, and it is common that candidates try the maximum three times that are allowed to pass the exam. To be chosen as a candidate for the civil service opens the way to a leading position in the government administration of India.

According to the interviewees, due to the heavy droughts during the last years, there have been a lot of households among the landless and the small scale farmers which have migrated to the nearby towns, especially to Hyderabad, in search of new work opportunities. Another common port of migration is the state of Gujarat, and there especially Mumbai, the capital of Gujarat and the business metropolis of India. In Mumbai, there are job opportunities particularly in cotton mills or other industrial sectors. It is a common practice that in the case of migration, the young men leave their home to find work and accommodation and later get married to a woman from the home village. The bride is then obliged to follow her husband and leave the village and family surroundings.

5.1.4. Children and education

Today, the majority of children attend school. Government schools are not ranked high in people's preferences because of their low standard of education, but they are free of charge and attended mostly by children of the poorer families. Wealthier families who can afford it may undertake significant investments in order to educate their children in private schools. In contemporary India, every child has the right, and is provided the possibility, to attend a school independent of caste or wealth of the parents. However, private schools and mission schools are most preferred and appreciated. According to many interviewees, only private schools may enable children to secure a place for further studies for higher degrees. The level of education among the interviewees was rather low, with 65 percent illiterate and only 11 percent with an education above 10^{th} grade (Figure 8). However, more than 90 percent of the children from the interviewed families attended government or private schools.

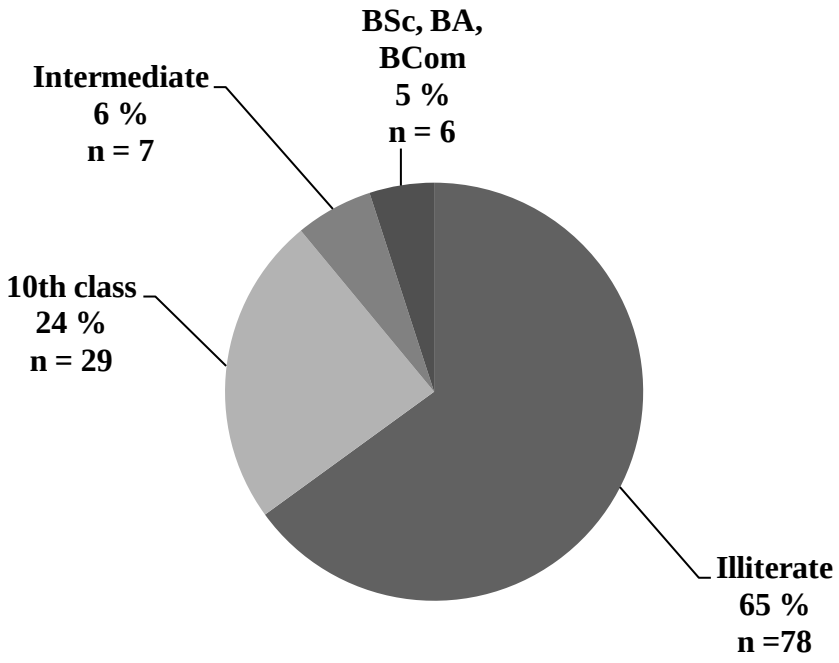

Figure 8. Level of education among the interviewees.

The families were very concerned about the upbringing and education of their children. It is common that the children stay at home with their parents until they move to the university campus for higher education or until they find a job and get married. When a young couple gets married, it is usually the bride who moves to the home of her husband's family or the newly-weds establish an independent house or apartment. It is also very common in India that the parents care for their children throughout their life but especially during childhood and young adulthood. After the parents have reached the age of retirement, it is, in turn, the duty of their children, and in most cases the oldest son and his family, to then support and care for them.

The school holidays in Andhra Pradesh take place during the months of the agricultural peak season, which enables many families to get support for their agricultural work from their children. Landless families might send their children to work as labourers during the crop season. In a few observed cases where children were not sent to school by their parents, they had to work in order to supply the family starting from a very young age. Besides agriculture, those children are also employed in different industry sectors and may live outside their home, being provided accommodation by the employer. In the coastal area of Andhra Pradesh, a brick factory entrepreneur first sent the children away before he was ready to give an interview. His first question was if we had anything to do with UNICEF or other child care organisations. He was aware of the prohibition of child labour but justified the employment of children with the need for cheap labour. Otherwise, he said, he would not be able to run his business. He was also sure to tell us that child labour is commonly practised in India, at least in the brick industry.

5.1.5. Household income

The income pattern of households in rural Andhra Pradesh differed among families depending on profession and land owning patterns. Farmers owning agricultural fields occupied the top range of the income pyramid. There are many factors that decide the annual income of local farmers, like the size of the agricultural holdings, water availability, soil fertility and climatic conditions. Owning agricultural land is a prerequisite for making a sufficient living in the rural areas. According to the information gained from the interviews, the annual income from farming depends on the crop variety and its market prices (Table 10).

Table 10. Investment, market prices and expected profits in agriculture.

(average; n=16)

Crop	Annual investment (Rs per acre)	Market price (Rs per quintal)	Expected annual net income (Rs/ acre) *
Paddy	5,000	600 - 650	15,000
Tobacco	4,000	2,500 - 4,500**	25 - 30,000
Groundnut	5,000	1,200 - 1,600	25,000
Sunflower	5,000	1,600 - 1,800	10,000
Cotton	5,000	2,200	22 - 25,000
Turmeric	5,000	2,100	15,000
Maize	3,000	500	10,000
Sugarcane	4,000	900 - 1,100	25,000

* Depending on water availability, climate conditions and current market price.
**First quality tobacco 4,500 Rs and second quality starting from 2,500 Rs.
(1 acre = 0.405 ha; 100 cents = 1 acre)

When asked about the allocation of the income from farming, in most of the cases, the answer was that any cash received is used for family maintenance. If money is left over, it will be used to acquire working tools or to cover the costs for maintenance and repair of the house or farm. Actually, most of the interviewed farmers reported that they are paying back loans that they had to take because of crop failure. In other reported cases, loans were obtained to cover the costs of medical treatment and drugs. It was also stated that livestock is an important component of livelihood as a way to store wealth. Livestock acts as a buffer in difficult times and diversifies the household income pattern.

Landless people are most vulnerable to any sudden crisis, like droughts or other misfortunes such as sickness. According to the survey, landless people were equally divided among the Scheduled Castes and Scheduled Tribes (SC/ST) and the Backward Castes (BC). The Forward Castes (FC) had the lowest percentage (25 %) of landless households (Figure 9).

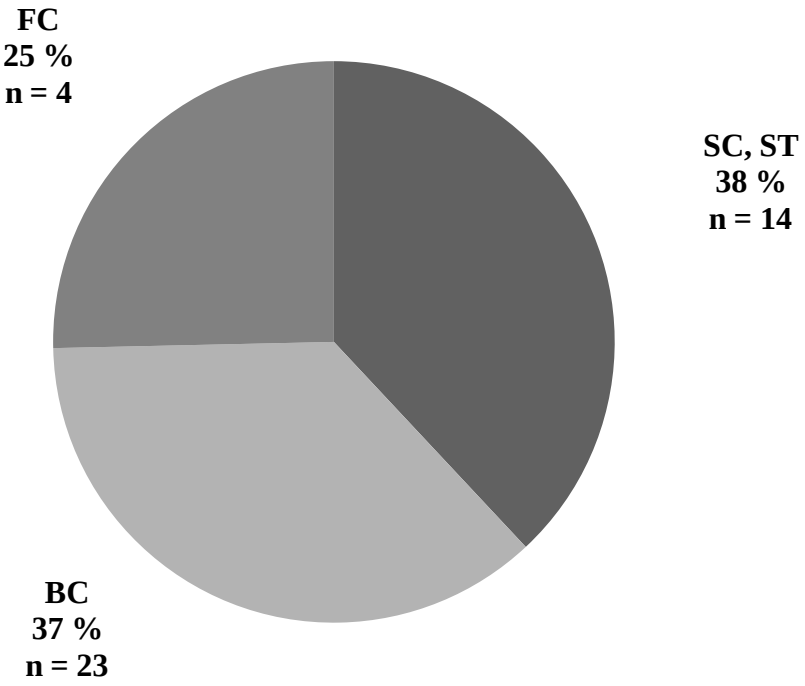

Figure 9. Landless households among different castes of the interviewees.

Among the interviewees, six percent of the landless families rented farmland for cultivation. For the underprivileged households from the SC or ST, the government provides housing and in many cases a piece of farming land up to one acre, depending on the size of the family. Since many of those families are not able to save any cash but need all the money that can be earned for current expenditures, the government grants cheap loans, usually with interest of one percent per month, in order to enable them to buy the necessary seeds and fertilizers for cropping.

There is a distinction in the amount of land owned by the different castes. Households belonging to the Scheduled Castes (SC) or Scheduled Tribes (ST) own generally smaller land plots for cultivation, with 62 percent of them smaller than two acres (Table 11). The distribution of landownership among the Forward Castes (FC) households is more evenly divided with the highest percentage owning land larger than 10 acres. Among the Backward Castes (BC), the highest percentage (36 percent) was found in those with an area between 5 and 10 acres.

Table 11. Size of landholding owned by households of different castes.

Caste	Land holdings (acres)	N*	Ownership (%)
SC, ST	< 2	8	62
	2-5	4	31
	5.1–10	1	7
	Total	13	100
BC	< 2	8	32
	2-5	7	28
	5.1–10	9	36
	>10	1	4
	Total	25	100
FC	<2	1	14
	2-5	2	29
	5.1–10	2	28
	> 10	2	28
	Total	7	100

N*: Number of respondents.

Families that do not own any land are either employed as labourers on farms or outside the agricultural sector. Workers in the Sai Baba tyre factory in Narasaraopet got a monthly salary of 3,000 Rupees, which is higher than the average labourer's income. Men work in two shifts of 12 hours, seven days a week. Families that live in the urban and semi-urban areas of Hyderabad and are not engaged in agriculture might find employment in the stone quarry enterprises that are located around Hyderabad.

Monthly expenditures in the rural areas of Andhra Pradesh were reported to be on average 4,000 to 5,000 Rupees for a household with four to five members. Poorer families need to make a living with 1,500 to 2,000 Rupees per month. The rent for housing is not included in the estimates since all of the interviewees were living in homes that they owned. The expenditure was counted for daily food, clothing, medicine, electricity and other necessary requirements of living.

Households of the lowest income categories are supported by the government through the distribution of "ration cards". A ration card enables the family to buy the basic items, like rice, sugar, and kerosene, from government distribution centres at subsidized prices. A "White Ration Card" holder is permitted to buy three items in restricted monthly quantities. Rice is restricted to 4 kg per month, per person living in the household. In addition, those households have the right to buy 1 kg sugar monthly for the entire family and 3 litres of kerosene every three months. The holders of "Red Ration Cards" are only entitled to buy subsidised rice. The same quality rice that costs 12 Rupees per kg in the local market is available for 5.50 Rupees per kilo through the government distribution that takes place once a week. The subsidised sugar price is 12 Rupees per kilo compared to 20 Rupees in ordinary shops, and the subsidised price for kerosene is 9 Rupees per litre compared to 20 Rupees on the market. In order to receive a White Ration Card, the annual income per household is restricted to a certain amount which is below the poverty line and also depends on the number of children. For the Red Ration Card, the income is calculated as being slightly higher.

5.1.6. Rural environment

When asking people's opinions about the condition and recent development of the environment, almost all the farmers were of the opinion that the environment has become considerably degraded during the last years. The last five years, especially, brought scarce and unstable monsoon rainfalls. The rainy season might have started normally at the expected time but suddenly it would be interrupted by a period of drought before the start of new rains. This scenario could repeat itself a few times during the regular monsoon period, thus causing major distress to farmers. With the onset of new rains, the farmers need to sow the crop seeds again, which are then more expensive than the previous ones. As a consequence, many farmers need to take loans, which force them into debt which they are not able to pay back with the sale of an even smaller harvest. In the local newspapers there are daily reports of farmers who commit suicide because they are desperately encumbered with debt. When they choose to end their life violently, most commonly through the ingestion of plant pesticides, they hope the government will pay compensation to their wives and children.

During the last few years, temperatures climbed to 50 ^{o}C during hot summers. Lakes and rivers dried out and left only cracking soils behind. Many indigenous plants were unable to stand the extreme climatic conditions and disappeared. In due consequence, prosopis invaded large areas of uncultivated lands. Although even irrigated agriculture is facing shortages of water during long drought periods, it is especially the farmers practising rainfed agriculture who suffered the most severe consequences in recent years. Irrigation with bore wells has become a difficult undertaking because the groundwater has dropped to such a low level that bore water is not enough to support crops towards the end of the growing period. The yields have remained low or in the worst case, crop cultivation has failed completely.

5.1.7. Urban environment

In the urban areas of Hyderabad, there is an ongoing transformation of agricultural lands into real estates for development. Because of the growing economy in Hyderabad, investors from within India and abroad are buying land to establish industries and to build an infrastructure for the rapidly increasing urbanisation. At the same time there is an ongoing migration from rural areas to the proximity of large cities as a consequence of decreasing wage work in the agricultural sector. The lacks of sufficient monsoon rains have forced many landowners to reduce crop production to family enterprises on smaller production areas. Consequently, agricultural labourers migrate to urban areas in search of new employment. The bulk of the migrating people is uneducated and often belongs to the lower castes. Most of them live in impermanent self-constructed accommodations and are in great need of daily firewood. For them, prosopis is an indispensible resource for survival.

The land in the urban areas around Hyderabad is relatively stony with scarce vegetation. Agriculture is reduced to small areas on the plains. Stone quarries dominate the rocky hill areas around Hyderabad (Figure 10). They create working places for men and women, producing specific sizes of stones for the road-building industry. After blasting the large blocks of stone, further processing is done manually by labourers. The vegetation is dreary and desolate and prosopis is one of the rare species, almost the only plant, that grows as a bush here and there. It is the only source of firewood for the workers, mostly rural migrants, who live in camps that are situated close to the working sites. These people use prosopis as firewood for preparing their meals and brewing tea. Other, more preveledged workers live in settlements of houses made of bricks and provided by the government. Those settlements are situated close to the areas where the stone work is done

Generally, interviewees who migrated to the urban areas indicated that they would rather live in their rural villages, if only they could make a living there. Migration into the new surroundings did not change anything connected to their status and caste. Also in their new surroundings the lower caste or casteless people remain on the bottom of the social hierarchy and suffer the most hardships.

Figure 10. Landscape near Hyderabad with *Prosopis* growing on the stony soil.
(Photo: Kurt Walter).

5.2. Agriculture in the study area

5.2.1. Farming in rural Andhra Pradesh

Farming is the main source of income in Andhra Pradesh. The cultivation of cash crops and, especially, paddy is most crucial for the income of the households. Although people are gradually migrating to urban areas because of the difficulties that farmers face due to droughts and shortages in water supply, agriculture is still the main income source for many different groups of people in rural Andhra Pradesh.

Among all the interviewed households, 55 percent did not own any land. Six percent of the families were tenants, renting farmlands for cultivation. Among the 45 percent of landowners, 39 percent inherited their fields from the family. The distribution of landholding sizes among land owners and tenants is shown in Table 12. Tenants pay their rent to the landowner as an annual monetary payment or they convey an agreed share of the harvest to the landowner.

Table 12. Landholding sizes of inherited and rented land.

	Type of land (%)			
Field size (acre)	Inherited land	N*	Tenants (rented land)	N*
< 2	41	16	50	4
2 - 5	31	12	38	3
5,1 - 10	20	18	12	1
> 10	8	3	0	0
Total	100	49	100	8

N*: Number of respondents.

One of the main criteria for the mode of cultivation is the availability of water. Most of the interviewed farmers (67 percent) practiced rainfed agriculture, which is entirely dependent on the monsoon rains. The Krishna and Godavari Rivers are the main water sources for the state of Andhra Pradesh. In close vicinity to those rivers, irrigated cultivation is practised whenever possible. The districts of West Godavari, East Godavari, and Guntur, through which those rivers flow, benefit especially from irrigation agriculture. The water is led through main canals to the proximity of the fields and reaches the crop fields through smaller canals or through water pumps. Andhra Pradesh is known as the “rice bowl” of India because of the state’s high yields in rice production, which is made possible due to these important water-supplying rivers. In irrigated farming, there is no piece of land that is not under intense cultivation.

One specific form of irrigation is through bore wells. Bore wells are used where the groundwater level is reasonably high. During the past years, many farmers practising bore-well irrigation have experienced a lack of water towards the end of the growing season. The level of groundwater has dropped too fast to supply water throughout the entire crop cycle, with negative effects on the outcome of the harvest. The cost for construction of a bore well depends on the groundwater level. The average price estimation ranged between 10,000-15,000 Rupees, which is more than a third

cheaper than it has been in the past decade. Although the construction of a bore well has become cheaper, farmers complained about the rising costs of electricity needed for pumping and the constant power cuts. Most of the interviewed farmers needed to take a loan to pay for the work.

5.2.2. Agriculture in urban areas of Hyderabad

Hyderabad, the capital of Andhra Pradesh with nearly five million people, has become the metropolis for technological development. Hyderabad is known to be the second most important centre for software engineering in South India after Bangalore, the capital of Karnataka State. As a consequence of the industrial growth, people from all over India are increasingly migrating to Hyderabad to look for work opportunities. The enormous expansion of the city during the last decade has caused many problems concerning infrastructure and space for housing and industry. The city is expanding to its margins and the real estate business is very profitable in the surrounding metropolitan area of greater Hyderabad. Real-estate agents are diligently buying land and infrastructure is rapidly developing, with streets and properties waiting to be sold whenever new industries reach the area. Land that is not cultivated or unsuitable for cultivation is generally invaded by prosopis. The new owners employ labourers to eradicate prosopis, even digging out the roots in order to increase the value of the land. Land prices increase all the time, and there is competition for the last acres of farming land. It is obvious that farmers are not getting a fair price for their land because they are mostly illiterate and not aware of the ongoing price speculations.

Due to the rapid development around Hyderabad, the international airport has become too small and a new airport is planned to be built south of the city at Shamshabad. Approximately 5,000 acres of land will be utilised for the construction of the airport in the Ranga Reddy District. Most of those acres are at present agricultural land. While conducting interviews in the suburban areas around Hyderabad one came across situations where real estate business people were trying to persuade farmers to sell their land, offering prices far below its real value. They offer to pay for the value as agricultural land. However, in a few years, the value of the land will exceed the price of today many times because of the nearness of the airport and the expansion of infrastructure.

The recent droughts have diminished and even emptied some of the city's water reserves. Thus, irrigated agriculture was out of question in those areas. It was even difficult to supply the growing population with drinking water, and during the investigation for this research, only a delayed but water-rich monsoon was able to save the inhabitants of Hyderabad and the surrounding areas from a dramatic water shortage.

There are several orchards found in the urban region with mango as the preferred species. The huge market for mango fruit in Hyderabad is a profitable business, with the condition that the weather conditions are suitable. According to two brothers who cultivate mangoes in the Reddy District, in an ideal season with no heavy rains or storms before the onset of the monsoon, their roughly 650 mango trees will bear 4-5 tons of fruit. Although prices fluctuate according to the mango harvest in nearby regions, they expect a sales price of 10,000 Rupees per ton of mangoes. After paying the 25,000 Rupees rent for the trees, the farmers' net income amounts to approximately 25,000 Rupees for the whole season. After the mango season is over, both farmers need to look for other work to earn their livelihood.

5.2.3. Agricultural seasons and crops

Type, structure and fertility of the soil and climatic conditions primarily govern the cultivation of agricultural crops. The availability of rain or irrigation water plays a significant role in all the phases of agricultural activity. The southwesterly monsoon is responsible for 80 to 90 percent of the rain on which agriculture depends. The timely onset of the monsoon and the proper amount of rain are crucial for a successful growing season.

The two major growing seasons in India are called *Kharif* and *Rabi*. During the *Kharif* season between July and December, when the southwest monsoon prevails, agricultural activities take place in rainfed as well as in irrigated areas. During the winter months between December and April, in the *Rabi* season, cultivation is only possible in irrigated areas.

Rice is the most important crop in Andhra Pradesh, and it is cultivated both under irrigation and as a purely rainfed crop. The time for rice to mature varies, with an average span from sowing the seed until harvest of about three months. The seeds are sown directly at the onset of the monsoon rains. Under the so-called semi-dry paddy cultivation system, the fields are flooded when the crop is about one and half to two months old and the seedlings are then converted into a wetland crop. If there are irrigation facilities, a second paddy rotation starts in December during the Rabi season and ends at harvest in April.

The availability of water and the quality and type of soil determine the crop selection of the farmer. Another important factor that decides the choice of the crops is the price fluctuations on the market and the positive correlation between economic input and possible economic gain. The most common crops cultivated by the farmers interviewed in Andhra Pradesh are listed in Table 13.

Table 13. Most common crops cultivated by the interviewees in Andhra Pradesh.

Common crops in Andhra Pradesh	
Groundnut (*Arachis hypogaea* L.)	Sunflower (*Helianthus annuus* L.)
Cotton (*Gossypium* spp., mainly *G. hirsutum* L.)	Tobacco (*Nicotiana tabacum* L.)
Chickpea (*Cicer arietinum* L.)	Pigeon-pea (*Cajanus cajan* (L.) Millsp.)
Cowpea (*Vigna unguiculata* (L.) Walp.)	Chilly (*Capsicum annuum* L.; *C. frutescens* L.)
Sugarcane (*Saccharum officinarum* L.)	Sorghum (*Sorghum vulgare* (L.) Moench)
Maize (*Zea mays* L.)	Finger millet (*Eleusine coracana* (L.) Gaertn.)

Cotton is commonly grown in the northern part of the Telangana area because it can adjust to the drier climate. The farmers who grow cotton cultivate the commercial ‘bt’ variety which is a genetically modified type with ballworm resistance. Groundnut and sunflowers are preferred crops because they require less economic input. Compared to the time before the years of drought, the yields have decreased, and farmers, especially in the drought-prone areas of Anantapur, complained about stagnating market prices due to growing import competition. Alternative crops for groundnuts in the rain-fed areas of Anantapur could be different varieties of fruit, but according to the farmers this would require too much cash input. Without irrigation, water harvesting systems, or alternatives

to groundnuts, the farmers in the drylands in Anantapur feel themselves highly vulnerable to both climate change and market fluctuations.

The crop cycles and duration of growth are different in rainfed and irrigated agriculture. The majority of the interviewed farmers practised rain-fed agriculture (Figure 11). The evaluation of the most common crops and their timings between seeding and harvesting shows the employment cycle of agricultural labour during the season. At the time of low activities in the fields, there is an increase in the activity of cutting and selling prosopis wood as an additional income. Although prosopis is mostly collected on a daily basis to be used as firewood, during the agricultural off-season the collection of prosopis wood becomes-time employment and an essential asset to livelihood.

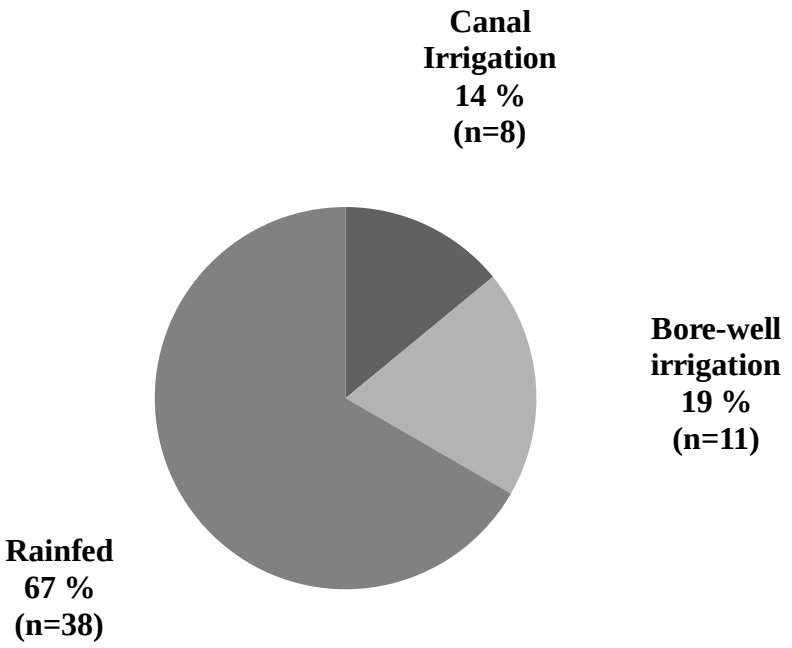

Figure 11. Distribution of different modes of cultivation among farmers.

The growing season in rainfed agriculture starts with the tillage of the agricultural field right before the onset of the monsoon rains. If the monsoon starts as expected during the second or third week of June, the tilling of the soil will start at the beginning of the month. June is generally the month of the highest activity in agriculture with the peak labour demand. The months between October and February, during which harvesting of the different crops takes place, are also highly labour intensive (Table 14).

Rainfed agriculture provides less employment and more insecurity than irrigated farming. Since it is totally dependent on the monsoon rains, it does not provide a secure income for either the farmers or for the labourers. In years of droughts it has been shown that prosopis provides some income when agriculture does not.

Table 14. Crop calendar of major crops in Andhra Pradesh for the rainfed agricultural season as reported by the interviewees.

Month / Crop	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Rice						S	T	G	G	G	H	
Groundnut	G*	H*				S	G	G	G	H	S*	G*
Sunflower							S	G	G	H		
Cotton						S	G	G	G	G	G	H
Tobacco	H							S	G	T	G	G
Sorghum	H										S	G
Sugarcane	G	H										S
Maize						S	G	G	H			

S = Sowing; T = Transplanting; G = Growing period; H = Harvest period.
* Groundnut can be sown immediately after harvesting the *Kharif* crop.

5.2.4. Livestock

Livestock provides economic security and helps in diversifying family incomes in Andhra Pradesh. In addition to supplying milk, eggs, or meat, bullocks and male buffaloes provide draught power for land preparation and for soil conservation practises. Livestock generates manure used for the maintenance and improvement of soil fertility and as a source of fuel when collected and dried in the sun. Some farmers grow green grass as livestock feed in a cut-and-carry system for their animals and to sell. Others use groundnut hulls, paddy residues or sorghum straw as animal feed. Yet another way to feed livestock is grazing the animals on the crop fields after the harvest has been extracted. Sheep and goats commonly graze on prosopis pods. It is also common to feed the animals with bran and with oil cakes after the oil has been extracted.

In the urban areas, fodder for livestock is rather expensive and often consumes half of the income from milk cows, since they need special feed. For many farmers livestock is a kind of income security in times of drought, when agricultural crop production fails because of lack of water. Other livestock owners earn an income by using their livestock as draught animals during the preparation of the crop fields.

Box 2. Livestock earnings: 3 examples

Water buffaloes and bullocks are used as draught animals. Virabhadra Rao, who does not own any farmland, is in possession of four buffaloes and one calf. He uses the two male buffaloes to earn money by preparing the crop fields for different farmers as paid labour. His salary is 100 Rupees for six hours ploughing. To feed his animals, he buys mainly hay, which costs him 3,000 Rupees and lasts for one year.

K. Ramakrishna, a 49-year-old farmer who cultivates 20 ha of agricultural land, uses his two male buffaloes as working animals for land preparation and the three female buffaloes for milk production. He gets six litres of milk daily, which he is able to sell to dairies for 10 Rupees per litre. The milk price depends on the amount of fat content and varies between 10 and 20 Rupees. Generally, the milk price is higher in urban than in rural areas.

The highest prices for milk are paid in Hyderabad and its surrounding suburban areas. T. Reddy is a migrant who moved from a village in the Nalgonda district to the suburbs of Hyderabad five years ago with his family and buffaloes. He left his village to find a new source of income. Rural life did not enable him to provide the means to feed his family. Frequently occurring droughts during the last years reduced the need for agricultural labourers and since he had no land of his own, he was forced to look for other work. Today, he owns 8 buffaloes giving 20 litres of milk daily. At a rate of 20 Rupees per litre he is able to make 400 Rupees a day. He spends about 50 percent of the monthly income for branded cattle feed which leaves him 6,000 Rupees per month for household use. According to his statement, the income is sufficient to support his family, which includes his wife and the three children who are still living at home. He also says that life on the outskirts of Hyderabad is much more expensive than in his village.

The three examples in box 2 indicate the importance of livestock for cash income in rural and in urban regions. For migrants it is often the best choice to maintain their livelihood, at least during the early period of migration. Interviews revealed that often one or several milk cows were the only assets they brought with them when they left their nearby villages. In the rural environment livestock provides an essential security for farmers and agricultural employees. Interviewees indicated that for many farmers it was a very important income source when droughts had destroyed their crop production and the only income they received came from selling part of, or all their livestock.

5.2.5. Home gardens

Houses and farm compounds in rural Andhra Pradesh generally consist of a garden that contains one or more tree species and various flowers (Table 15). In the home gardens of the poor people one may find only one tree, which is most likely a prosopis tree. It is often growing in the middle of the yard as a source of shade for the family and livestock. It is a common sight to find a bullock or

cow tethered to it. Prosopis trees are either planted intentionally or they start growing through natural seed dispersal. The home gardens of more wealthy households may consist of several tree species and flowers or plants of different species.

Table 15. Observed plant species in home gardens.

Plants in home gardens		
Tree species	**Fruit trees**	**Flowers and herbs**
Bamboo (*Bambusa* spp.)	Badam tree (*Terminalia catappa* L.)	Curry leaf tree (*Murraya koenigii* Spreng.)
Banyan (*Ficus benghalensis* L.)	Banana (*Musa paradisiacal* L.)	Hibiscus (*Hibiscus rosa-sinensis* L.)
Bodhi (*Ficus religiosa* L.)	Citrus (*Citrus* ssp.)	Jasmine (*Jasminum* spp.)
Casuarina (*Casuarina equisetifolia* L.)	Custard apple (*Annona squamosa* L.)	Lily (*Lilium* spp.)
Coconut (*Cocos nucifera* L.)	Drumstick (*Moringa oleifera* Lam.)	Oleander (*Nerium oleander* L.)
Eucalypts (*Eucalyptus* spp.)	Gooseberry (*Emblica officinalis* Gaertn.)	Rose (*Rosa* spp.)
Jungle geranium (*Ixora coccinea* L.)	Guava (*Psidium guajava* L.)	Tulsi (*Ocimum sanctum* L.)
Neem (*Azadirachta indica* A.Juss.)	Mango (*Magnifera indica* L.)	
Prosopis (*Prosopis juliflora* (Sw.) DC)	Papaya (*Carica papaya* L.)	
Sal (*Shorea robusta* C.F. Gaertn.)	Pomegranate (*Punica granatum* L.)	
Sissoo (*Dalbergia sissoo* Roxb.)	Sapodilla (*Manilkara zapota* (L.) P.Royen)	
Subabul (*Leucaena leucocephala* (Lam.) de Witt)	Tamarind (*Tamarindus indica* L.)	
Sugar palm (*Borassus flabellifer* L.)		
Teak (*Tectona grandis* L.f.)		

Many flowering plants are intentionally planted and managed. Flowering plants are appreciated for their beauty and fragrance, and herbs are used as traditional medicines for many ailments. Fruit trees are generally found in more spacious home gardens. These trees are managed and the fruits and vegetables are generally used for subsistence needs. The immature green pods of the Moringa tree (*Moringa oleifera* Lam.), which is known as drumstick, and leaves from the “curry” tree

(*Murraya koenigii* Spreng.) are essential items in Indian cooking. For this reason these trees are frequently present in home compounds. In larger home gardens mango trees are also grown and the fruits are sold on the market. In more drought-affected areas in Rajalaseema, fruit trees are grown in home gardens in order to diversify agriculture. Compounds with more space cultivate several tree species. Mangoes, bananas, pomegranate, papaya, citrus and many more fruits and herbs bring an additional income to supplement crop cultivation. During years of drought, when agriculture had failed, the income from those trees saved many households from the worst economic crises.

Small scale home gardens are usually managed by women. While men are caring for the crop fields, women take over the responsibilities for their home gardens. However, women and children do participate in agriculture through weeding the crop fields several times during the growing period. An old lady interviewed in her home compound indicated that the dozen fruit and vegetable trees and her small livestock, consisting of three goats and a few hens, has been her only source of livelihood after her husband's death. She sells extra fruits and vegetables on the market. On a few occasions she receives small amounts of money from her children.

5.2.6. Farm forestry

Besides home gardens, tree plantations on farmlands are another diversification strategy among farmers and landholders in rural Andhra Pradesh. In the Prakasam District, a significant proportion of the soil is highly saline and alkaline. Also the groundwater has turned saline at several places and is unfit for irrigation. The main cash crops grown under those conditions are tobacco, cotton, chilly and paddy. In these areas, farm forestry has become popular and species like subabul (*Leucaena leucocephala*), casuarina (*Casuarina equisetifolia*), and eucalypts (*Eucalyptus* spp.) are appreciated as plantation trees. However, trees are not grown intentionally on the same site with agricultural crops to increase the total yield of products. Either they occupy the entire field or they are planted along the borders of crop fields.

On a small-scale level, the trees are planted around crop fields, in narrow rows and at short distance from each other as boundry plantations. Teak (*Tectona grandis*) is most preferred for this purpose, while casuarina is more often planted on the entire field in large numbers. Fluctuations in the tobacco markets and pest problems in cotton fields are reasons for farmers to shift to the alternative of growing trees on farmland. Forest authorities encourage farmers to practice farm forestry and supply farmers with seedlings of genetically improved varieties at convenient prices. Many farmers get supplied with high-yielding clones of eucalypts from wood enterprises with the guarantee that they will buy the wood for a fixed price after the rotation. In the last instance it is still in the hands of the farmer to decide to whom he sells the wood.

Casuarina trees are grown on sandy soils in the eastern parts of Coastal Andhra with an optimal rotation of seven years. The trees have then reached a height of approximately 10 m and a minimum diameter of 5 cm. The stems are preferred for use in the building industry to support roof construction during building work. A distinct advantage of casuarina is its ability to fix atmospheric nitrogen, although it is not a leguminous tree.

In the state of Tamil Nadu, geographically to the south, the farming patterns are similar to those in Andhra Pradesh due to similar climatic and soil conditions. However, the investigation revealed an even more distinct increase in conversion of farmland into tree plantations in Tamil Nadu. One of the reasons for this trend is the increasing migration of labourers to towns and urban centres. The

continuing expansion of the economy of India requires high labour input in the building trades and in the industrial sector. The salaries are considerably higher than the earnings from agricultural work. The labourers who remain in the rural communities demand higher salaries because of the labour shortage, which the landowners are not willing to pay. A shift to farm forestry seems to be an easy way out of the dilemma. Another reason given by people for the preference to grow trees on farmland is connected to climatic fluctuations. Farming on rainfed lands is entirely dependent on the monsoon rains.

During the last years, the monsoon rains have become unpredictable and have failed to supply a sufficient amount of water. However, trees, once established, need less water to survive and grow since they are able to tap water from deep soil layers through their root system. Another hazard is experienced when the monsoon rains pour down with such intense force that the water washes over the fields without penetrating into the soil. In the worst cases, the water washes away the top soil that contains most of the nutrients needed for crop cultivation. Trees are prefered because they are not as sensitive to weather conditions as field crops. Farm forestry is also practiced in Andhra Pradesh but not with such intensity as in Tamil Nadu.

5.2.7. Aquaculture in the coastal areas

Brackish water aquaculture was introduced in the coastal areas of Andhra Pradesh in the 1980s. Mr. Surendra, an aqua farmer from the village of Kottakodura near the city of Nellore, reported that he started to convert agricultural land into prawn ponds seven years ago. By that time the prices for commercially valuable species, like tiger prawns or crabs, were climbing and once the initial investment was done it was believed to be a profitable and less labour-intensive business. He invested more than one *lakh* (100,000 Rupees) to build the ponds and install the necessary machinery. In addition to the high initial investment, aquaculture is a capital intensive undertaking, which requires high amounts of monetary input to buy the hatched foy from breeders and to buy the special feed that is required. Although the enterprise was quite lucrative for the first few harvests, during the last years a pest called “white spot disease” appeared among his tiger prawn populations. This capital-intensive enterprise based on live creatures has proved to be vulnerable. Together with increasing competition and reduced prices, which are mostly dictated by traders, the whole undertaking is not viable anymore and it has turned out to be the wrong investment for him.

Similar statements were made by other farmers engaged in aquaculture. In the coastal areas where the Krishna River enters the Bay of Bengal, there are numerous empty ponds and farmers are converting the land back to crop cultivation. According to farmers who practise crop cultivation on re-converted aquaculture lands, there is no problem with soil fertility or salinity, although the soil has been affected by seafood cultivation for many years.

However, what has become a problem is the growing invasion of prosopis along the banks of the irrigation canals. On the other side, a change from aquaculture to more labour intensive agriculture creates new work opportunities. According to interviewees, prosopis provides them with additional firewood resources. Weighting the pros and cons, the majority of the interviewed aquaculture farmers were positive about the re-conversion to crop fields and the continuation of agriculture.

5.3. Prosopis in Andhra Pradesh

5.3.1. *Prosopis juliflora*, an exotic tree as a natural resource

Prosopis has been a part of the environment in the semi-arid regions of Andhra Pradesh for more than one hundred years. In different areas of Andhra Pradesh, people have given local names to prosopis. Although prosopis has been grown in Andhra Pradesh for such a long time, the species has started spreading into new areas only during the last three or four decades. The tree has been seen or recognised during the last twenty years by almost all the people asked. It is also common knowledge that prosopis is an exotic species that has come to India from somewhere "outside". However, the tree that is visible everywhere today has not gained an equal valuation compared with local tree species, despite the fact that it is used as an important resource by the majority of people. In the various regions of Andhra Pradesh, prosopis is called by different names, which often express the attitude of the people towards prosopis (Table 16).

In the Ongole District prosopis is called "chilla karra" which means "waste stick" or "adavi karra", forest stick. Prosopis usually grows in dense thickets and the size of the stem is comparable with the size of a wooden stick with diameters of less than 8 cm. In the urban and suburban regions of Hyderabad, people call prosopis "sarkar thumma". The word sarkar means government in Hindi and in Urdu, spoken by the large Muslim community, with thumma standing for prosopis tree. Sarkar thumma means the government tree and has got its name because it usually grows on wasteland, which is commonly owned by the government. The word thumma denotes a number of especially thorny tree species which include *Acacia nilotica* (L.) Delile, usually called black thumma. The wood of *A. nilotica* is slightly darker than that of prosopis.

In many parts of the Godavari District prosopis is called "kanchi vittanum chettu"; "kanchi" meaning fence and "vittanum" means seeds. Chettu is the Telugu word for tree. Another name used in the region is "piyya thumma chettu", with "piyya" meaning faeces of goats. Goats graze on the pods of prosopis and spread the seeds through their faeces. The name "dhadi thumma" (fence tree) is used in the local slang of the Telangana region.

Most commonly the local name of prosopis derives from its use, like the name "kanchi thumma", fencing tree. Another practise is to name the tree according to its morphological appearance. In Tirupati, a famous holy town in the Chittor District, the trading name for prosopis is "mulla karra" or "sarkar karra" with "karra", standing for stick and "mulla" meaning spines.

Table 16. Summary of local names for *Prosopis* and their meaning.

Local name	Translation
Sarkar thumma	**Government tree**
Chilla karra	**Waste stick**
Adavi karra	**Forest stick**
Kanchi vittanum chettu	**Fencing seed tree**
Dhadi thumma	**Fence tree**
Kanchi thumma	**Fence tree**
Piyya thumma chettu	**Thorny tree from goat faeces**

When asked about the origin of prosopis, the interviewees answered with different narratives. In some villages near the coastal area of Kakinada, the villagers had their own version of how the tree first arrived in Andhra Pradesh. According to their stories, it was the former Prime Minister, Pandit Nehru, who in the early 1950s ordered the seeds to be distributed from helicopteres in the rural areas. It was said that he himself took part in the operations. When asked about the possible provenance of the seeds, it was commonly mentioned that the British authorities brought the seeds from Africa to intentionally plant them all over India. It was debated among the interviewees that the main reason for bringing prosopis into India was its use as fencing material and as fuelwood.

In Nellore, the capital of the Nellore District, close to the seashore, prosopis is called the "Japanese tree"among the villagers. People talk about a huge flood that arrived at the coast from Japan in the 1970s that had washed the prosopis seeds ashore, and then the seedlings started to invade the uncultivated fallow lands. However, there is no prosopis invasion in Japan that would make possible such a transfer of seeds via the sea. According to several interviewees, the continued invasion from then on was due to the goats and sheep that feed on prosopis pods and spread it through their faeces.

When the interviewees were asked when they first became aware of prosopis, older people remembered that they saw the tree about three to four decades ago for the first time. Since then, according to the observations of some senior participants in various group discussions, the tree has spread with great speed, especially during the last twenty years.

A majority (65 %) of the interviewees perceive an increase of prosopis during the last few decades. While some of the people think that prosopis has been reduced due to its increased use, other interviewees observed that the increased use of the wood also increased its spreading. A minority suggest that the distribution of prosopis trees has remained constant during the last years (Figure 12).

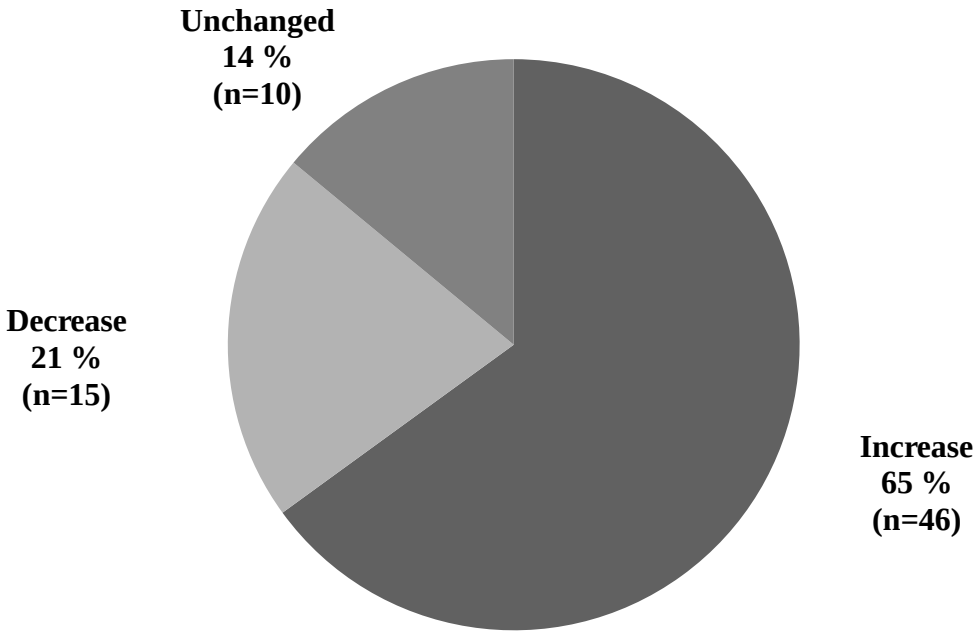

Figure 12. Perception of the invasiveness of *Prosopis.*

5.3.2. People's perceptions and opinions about *Prosopis*

The result of the investigation of the general opinion of people about prosopis was categorized into three different statements:

1. *Prosopis is a good tree and a valuable natural resource,*
2. *Prosopis is not very useful to people and even harmful to the environment,*
3. *No strong feelings towards the tree; it is neither good nor bad.*

The uses and services provided by prosopis were equally appreciated by both genders. Firewood was emphasised more by women while living fences were valued more by men. None of the female interviewees who responded to the above question had a definite negative opinion about the tree although seven women were neutral about prosopis (Table 17). One of the reasons for not neglecting prosopis is the fact that women who use fuelwood for their daily cooking are especially dependent on the tree as a source of fuel. Men's opinions are more negative. For men, prosopis means additional work when the tree invades crop fields. Men are also involved in the heavy work of cutting the trees that are then carried by women.

Table 17. Perception of value of *Prosopis*.

Opinions about prosopis	Perceptions of interviewees					
	Women		Men		Total	
	N*	%	N*	%	N*	%
Positive	13	65	60	62	73	63
Negative	0	0	19	20	19	21
Neutral	7	35	18	18	25	16
Total	**20**	100	**97**	100	**117**	100

N*: Number of respondents.

People who held a positive attitude about prosopis mentioned several services and virtues of the tree that they appreciated. However, even the interviewees who had a negative opinion recognized the value of the tree for various services provided by prosopis. A frequent comment by a group was that although the tree is quite useless it is important as firewood and especially for the poor people. Since women traditionally take care of cooking, they were rather satisfied that fuelwood is available and even close to their houses. As negative aspects of prosopis, the difficulty to handle the tree was often mentioned. Its use as fencing material also plays an important role among the usages of prosopis (Table 18). There were also complaints about the injuries the thorns frequently cause to humans and animals.

An important argument for the claim that it is especially a promising resource for the poor is the fact that the trees are widespread on wasteland which is usually owned by the government. These trees are free to be cut and used by anybody without limitations. Prosopis trees growing on private land are only allowed to be used with the permission of the landlord.

Men who earn their living from cutting and selling prosopis wood expressed mixed feelings about the tree. Many complained that it is a very hard work to cut the tree because it is stringy and it has thorns. However, since it has become an important income source for many households it is commonly appreciated because it is free and easily available.

Table 18. Acknowledged uses and services of *Prosopis*.

Acknowledged uses and services of prosopis	Opinions about acknowledged services of prosopis by the interviewees						
	Positive		Negative		Neutral		Total
	N*	%	N*	%	N*	%	N*
Prosopis is an important source of firewood	43	52	11	69	11	58	65
Prosopis is useful for bio-fencing	20	24	2	13	7	37	29
Prosopis provides shade for humans and animals	16	19	1	6	1	5	18
Prosopis is a very important natural resource for poor people	4	5	2	12	0	0	6
Total	**83**	100	**16**	100	**19**	100	**118**

N*: Number of respondents.

Because of intensive agriculture, which is generally managed on privately owned lands, prosopis has been and is still today used by farmers as live-fences to protect their crop fields from the encroachments of animals. Farmers are aware of the potential dangers of an invasion of the tree into their fields and pull the seedlings out of the fields immediately when they appear. In those areas in close proximity to the water resources of the two holy rivers, the presence of prosopis is less dominant.

Along the coast line from Srikulam District in the north to the Chittor District in the south of Coastal Andhra, the soil is highly saline and only a limited number of plant species are able to survive. Prosopis has adapted well to those soils and appears abundantly as a monoculture. As a result, people have adopted their daily needs to it and use the tree in many different ways, especially as fuelwood. The people in Coastal Andhra, in general, had a rather positive opinion about prosopis (Table 19).

The region of Rayalaseema in the southwest of Andhra Pradesh is classified as an extremely drought-prone area, especially in the districts of Anantapur and Cuddapah. Prosopis has adapted well to the dry and hot circumstances and grows almost everywhere. There are very few other tree species that are found scattered in the area and the Forest Department has put a ban on the utilization of any tree species other than prosopis. Although the farmers struggle with prosopis invading their fields, more than 80 percent have a positive opinion about the tree.

Telangana, the most northern region of Andhra Pradesh, is supplied with water from the Godavari River which makes irrigated agriculture possible. In the Nizamabad District intensive irrigated agriculture is practised and prosopis occurs with only low intensity. This region is surrounded by hill slopes with natural teak forests. People are not allowed to cut any trees from the forests but they may harvest branches from pruned trees. Besides teak (*Tectona grandis*), other common species found there are terminalia (*Terminalia arjuna* (Roxb. ex DC.) Wight & Arn.), Indian kino (*Pterocarpus marsupium* Roxb.), acacia (*Acacia nilotica*), tamarind (*Tamarindus indica*), and neem (*Azadirachta indica*). Some of those tree species are allowed to be partly utilized and are usually the first choice.

One of the interviewees put it this way:

> *"Why should we use a tree that is so difficult to handle causing even injuries when there is the possibility to use other species?"*
>
> (Comment of a male interviewee during a group discussion).

Table 19. Opinions about *Prosopis* according to region.

Region	Opinion	N*	%
Coastal Andhra	Positive	54	64
	Negative	9	11
	Neutral	21	25
Total		**84**	100
Telangana	Positive	10	45
	Negative	9	41
	Neutral	3	14
Total		**22**	100
Rayalaseema	Positive	9	82
	Negative	1	9
	Neutral	1	9
Total		**11**	100
Grand total		**117**	

N*: Number of respondents.

In the neighbouring Karimnagar District of Telangana, where cultivation has been difficult because of less rain and the dominance of rainfed agriculture, prosopis is more abundant and has invaded many rice fields that have been out of cultivation, causing farmers a lot of extra work. People in this area have a stronger aversion towards prosopis, which is expressed in their opinions. In the Warangal District of the same region, wasteland areas that are usually covered with prosopis are increasingly cleared and converted into eucalypt plantations.

The perceptions of farmers and common village people are mostly determined by the way people use the tree. Practicing foresters and scientists look at prosopis from a different angle. The opinion of the officials of the Department of Forestry was that prosopis has the very important function of keeping the people out of the protected forests. There is an immense need for firewood and without the free and easily available prosopis resource it would be difficult to stop people from using those other protected forests. One of the officials was even very enthusiastic:

> *"Prosopis is a present from god given to the poor people for their survival."*
> (Forest official).

Another forester pointed out the need for, and benefit from, studies that would deal with probable market uses of prosopis. He stressed the underlying dangers of an increasing invasion of the alien tree. However, he stated that the financial resources for research on these issues are very limited. It is mainly the economically valuable species like teak that get research financing from the government.

The interviewed scientists from three main universities across Andhra Pradesh were also aware of the various benefits provided by prosopis, although they expressed their worries about the extended invasion of the tree that has taken place during the last two decades. Dr. Vatsavaya Raju, Professor of Plant Science at the Kakatiya University in Warangal, pointed out that wherever prosopis invades land it suppresses indigenous plants and reduces biodiversity. He is also concerned that the natural flora, especially birds, will suffer the consequences of a further invasion. Dr. Raju is of the opinion that the state government is not really aware of the danger that a further uncontrolled spread of the tree will cause to the environment. He feels that politicians and decision makers are not listening to the concerns of scientists. He continued by saying that as long as people are happy with prosopis because of its multiple uses, no silvicultural measurements to control the invasion of prosopis will be implemented.

There are a few opinions concerning prosopis that are shared by the majority of people independent of their gender, age, region or profession. Those generally positive statements concerned the free availability of the tree for the poor people and its value as fuel in rural areas. While some farmers discussed the use of prosopis as live-fences and appreciated the shade the tree provides, farmers in drought affected areas were worried about the invasion of the tree into their crop fields. Urban and city people were not very concerned about prosopis since they use more and more gas for cooking and other fuel needs. Landless people with a shortage of work opportunities, and, thus a lack of monetary income, appreciated the tree as a resource that provides livelihood income. Opinions of the benefits and detriments caused by prosopis and expressed by the people interviewed are summarised in Table 20.

Table 20. Summary of benefits and detriments of *Prosopis* as perceived by the interviewees.

Benefits	Detriments
• Important resource of fuelwood and charcoal • Provision of construction material for huts and impermanent houses • Provision of shade and shelter for humans and animals • Provision of main and additional household income • Free availability for anyone • Use as live-fences to protect crop fields from encroaching animals • Dried prosopis branches for the protection of yards and fodder places • Usage for agricultural tools and bullock carts	• Invasive, causing economic and ecological damage • Difficult to cut and handle • Reduction of biodiversity • Thorns that cause injuries • Refuge place for harmful animals • Low quality wood to manufacture low quality furniture • Releases smoke that causes pain in lungs • Reduces the value of any real estate property

5.4. Different uses of Prosopis

5.4.1. Fuelwood

Prosopis is used for many purposes, providing a cheap and easily available natural resource for everyone that can be used as fuel or as raw material for many objects. The most common use of prosopis is as fuelwood. Almost every one of the interviewees used prosopis as firewood (Figure 13). Even if gas facilities are available, it is still common to use firewood now and then. Especially among the landless and poor, prosopis is the only available heating resource to prepare their meals. Hyderabad is a fast expanding city in India with a blossoming building industry. New IT High Tech centres are being built continuously. Huge temporary villages of construction workers rise beside the new building projects and the labourer families are totally dependent on prosopis as firewood. It is usually the whole family, including children, who live in those places and work for the building companies. The poorly constructed huts commonly consist of a frame made of prosopis stems and encased by plastic covers or dry leaves. Outside the huts, families store prosopis branches which are collected from the nearby wastelands for firewood. When the project is completed, the huts are easily dismantled and shifted to another place.

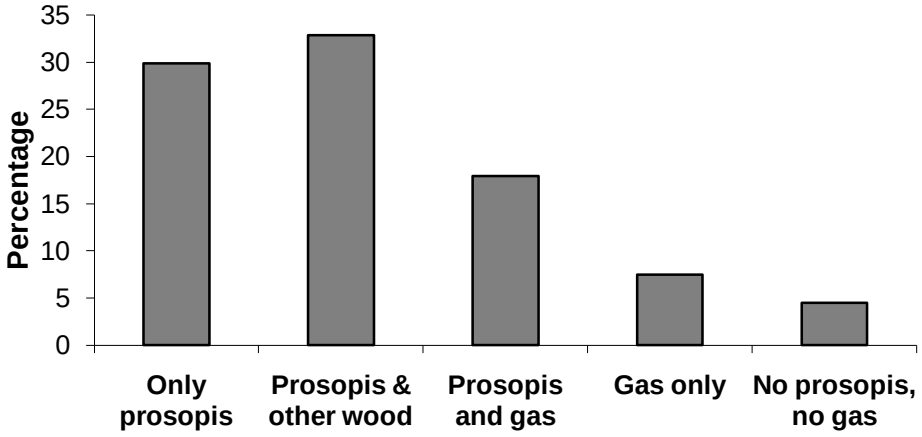

Figure 13. Sources of fuel among the interviewees.

Although the use of liquid gas is becoming more common in India, for most of the rural families in Andhra Pradesh, firewood is still the most essential source of fuel. It is used, especially, by the poor people who are landless, mostly seasonal labourers, who can not afford gas facilities. There is also a difference among Hindu castes in the use of fuelwood (Table 21). Among the Scheduled Castes and Scheduled Tribes, of the interviewed households, the use of prosopis as firewood is highest, with only one household using gas. On the other hand, households of the Forward Classes have the highest rate of gas use.

Farmers who are economically better off use gas, but after the growing season is over, they often engage in cutting prosopis for firewood. Often, those families using both gas and firewood as household fuel use the latter mainly for boiling water to prepare tea. Gas is then used for cooking the daily meals. The costs of the basic facilities needed for the use of gas is on average 2,000 Rupees as a one time investment. This is too high a sum for most of the landless people. In addition, one cylinder of bottled liquid gas costs 280 Rupees.

The collection of firewood for daily use is done mostly by women, although men might cut the shrubs into lengths suitable to be carried by women. The average household consumption of fuelwood varies from 3 to 6 kg/day according to family size (approximately 1.3 kg per capita/day). The cutting of prosopis for commercial purposes is frequently done by men because it is tough work that needs physical strength.

Mr. Ramulu lives with his wife and three children in the suburban area outside Hyderabad. He divides his monthly needs for household fuel into firewood and gas. His household consumes monthly 1 cylinder of bottled liquid gas (280 Rs/ cylinder) and 60 kg of fuelwood, mainly prosopis (3 Rs/ kg).

Mr. Ramulu commented that:

> *"...my wife is very fond of using gas for cooking because she says it is so comfortable. Still we cannot afford using only gas; so, we also need firewood. Because I have no time to collect the wood, we buy it on the market".*

Table 21. Distribution of fuel use among Hindu castes.

Caste		Source of fuel	N*	%
SC, ST		Only prosopis	11	42
		Prosopis & other wood	7	27
		Prosopis & gas	6	23
		Gas only	1	4
		No prosopis, no gas	1	4
	Total		**26**	100
BC		Only prosopis	13	33
		Prosopis & other wood	13	33
		Prosopis & gas	6	14
		Gas only	4	10
		No prosopis, no gas	4	10
	Total		**40**	100
FC		Only prosopis	2	18
		Prosopis & other wood	4	37
		Prosopis & gas	3	27
		Gas only	2	18
	Total		**11**	100
Grand total			**77**	100

N*: Number of respondents.

The use of gas is increasing in the larger towns and semi-urban areas. In the rural areas, gas is still the privilege of the more wealthy families who own land and practise farming. Among the interviewed households, 55 percent were landless and 45 percent owned some land for cultivation. There are landless people among all the castes and also among Christians and Muslims. However, the majority of landless belong to the Scheduled Castes and Scheduled Tribes. They are among the households that are most dependent on the availability of prosopis as fuelwood (Figure 14).

Prosopis is generally appreciated as good quality firewood. However, since the thorny tree is difficult to handle, the interviewees prefer to use alternative species as firewood if any are available. Once prosopis wood has dried, it is very difficult to cut into suitable pieces to be used as fuelwood. Some of the interviewees also complained that the smoke of prosopis wood causes them to cough, which might be a consequence of the tannins in the wood. Among the landless people, 91 percent use prosopis in one way or another, with 39 percent using only prosopis. Households with access to land have increased the use of gas because it is comfortable and has become affordable for them (Figure 15).

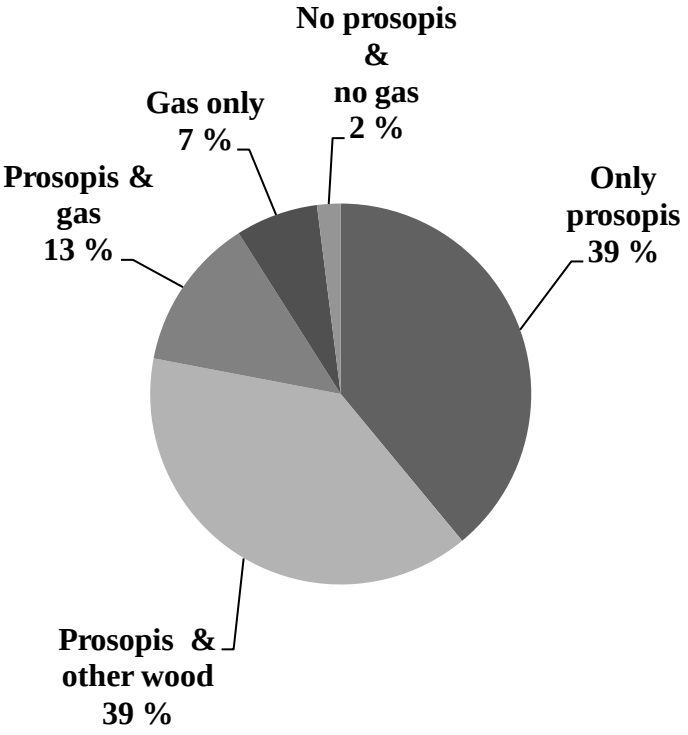

Figure 14. Fuel use of landless farmers.

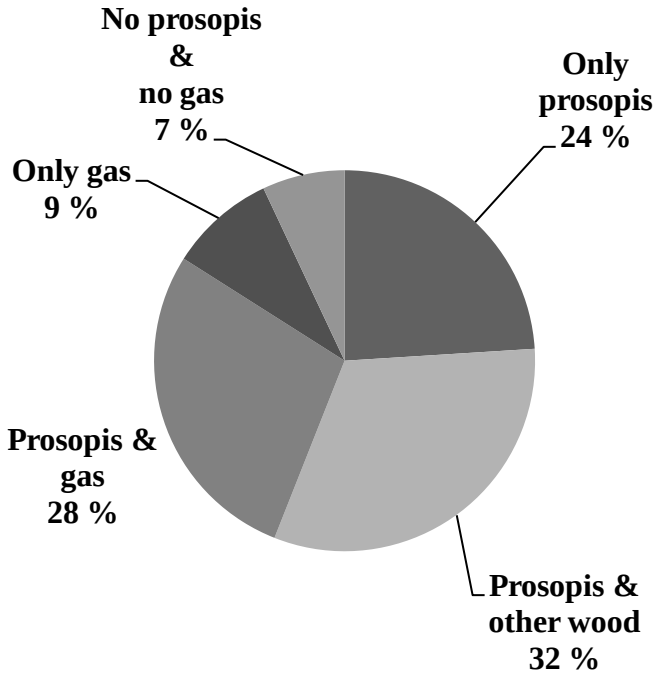

Figure 15. Fuel use of land owning and tenant farmers.

A common use of prosopis as firewood is at wedding parties. The taste of the food that derives from the use of this good smelling wood is said to be appreciated by the customers. Hotels and restaurants use prosopis as fuelwood processed as charcoal for preparing food. When the land on which prosopis grows is privately owned, it is a custom that the family of the couple to get married usually gets permision to cut prosopis for the preparation of their marriage meals, as a wedding present.

Funerals are occasions where prosopis is used because the wood is cheap compared to other species. The majority of Hindus cremate their dead on a pyre at specially assigned cremation sites, preferably close to a holy river or shrine. In rural areas, the family members of a deceased relative usually collect the necessary firewood for the pyre, and in urban areas, it is purchased from local wood sellers. The expenditure for the wood that is needed for a funeral pyre varies between 250 – 500 Rupees, with prosopis as the cheapest option.

Treatment of Prosopis injuries

The thorns of prosopis often cause injuries to people who handle the tree. Those who are frequently in contact with prosopis have developed techniques that save them from getting hurt. Once a thorn has penetrated the skin, complications are most commonly caused by the hull covering the thorn. The hull may remain in the wound after the thorn itself has been removed and it can cause acute infections. In those cases, people must consult a doctor for treatment. In less severe incidents, it is common practice to produce a paste made from the green leaves of prosopis, which is applied to the

wound. To produce the paste, leaves are first boiled for a while and later pounded in a mortar. This practise is common knowledge among many rural people in Andhra Pradesh.

Some interviewees reported that it was common practise in earlier days to pour kerosene on the wound and light a fire in order to burn out the hull that remained in the flesh. After this procedure, leaf paste prepared as described above would be applied. This use as a cure for injuries caused by the thorns was the only medical property of prosopis that was mentioned by the people interviewed.

5.4.2. *Prosopis* used as furniture

The use of prosopis as a raw material for furniture is limited because it is considered to be of low quality and the wood easily splits and bends. Prosopis wood is also claimed to become easily infested with wood destroying insects. One of the interviewed carpenters stated that the sapwood of prosopis is of bad quality and hardly suitable for furniture at all. Only the mature wood (dead heartwood in the inner part of the stem) is durable and can be used for certain furniture. A common use of prosopis is for the construction of cots, a kind of bed with a frame and legs made of wood and jute strings as the middle part to sleep on. The legs are usually constructed of prosopis while *Acacia nilotica* is often used for the frame. One cot is sold for 150 Rupees and a small enterprise with five to eight employees can sell up to ten cots daily and repair another five.

A few carpenters said that they sometimes constructed tables or chairs made of prosopis wood that had been ordered by people who owned sufficiently large trees (minimum of 30 cm diameter), which were processed in sawmills. Door and window frames are also occasionally manufactured from prosopis as a cheaper alternative to the more common, but also more expensive, use of wood from the neem tree (*Azadirachta indica*). The three most commonly sold timber species are prosopis (*Prosopis juliflora*), black thumma (*Acacia nilotica*) also called the black prosopis, and neem (*Azadirachta indica*). Timber is sawn to planks of 12 cm thicket which is commonly used for manufacturing furniture. The sawmill purchases and retails the wood in the price categories outlined in Table 22.

Table 22. Timber prices of the three most frequently sold woods.

Wood species	Purchase price Rs/ ton	Retail price Rs/ m^2 (12 cm thick)
Prosopis	700	20
Acacia nilotica	1,200 – 1,300	25
Azadirachta indica	1,500 – 1,800	30

According to the sawmill operators, there is a great demand for suitably large-sized trees with a preferred diameter of 60 to 90 cm, which are difficult to get. Prosopis or black thumma stems of such diameters would accrue a price of 1,500 to 2,000 Rupees per ton.

Poor people, who cannot afford any other alternative, use prosopis for making furniture or floors and ceilings. According to the knowledge of the carpenters interviewed, the most appreciated wood

for those purposes is teak. It is regarded as the highest quality wood but it also has the highest price and is, therefore, only affordable by wealthier people (Table 23).

Table 23. Ranking of tree species used for furniture.

Classification rank
1. **Teak (*Tectona grandis*)**
2. **Rosewood (*Dalbergia latifolia*)**
3. **Indian kinowood (*Pterocarpus marsupium*)**
4. **Neem (*Azadirachta indica*)**
5. **Black thumma (*Acacia nilotica*)**
6. **Prosopis (*Prosopis juliflora*)**

5.4.3. Agricultural equipment and tools made of *Prosopis*

Bullock carts are constructed of wood and pulled by buffaloes or cows for transporting goods, mostly agricultural products. Such vehicles are indispensable in Indian agriculture. If available and affordable, *Acacia nilotica* is the preferred wood used for the construction of bullock carts. For the poorer farmers, prosopis, although considered as a lower quality raw material, is used to build the middle part of the carts. If there are no other resources, prosopis is even used for the whole construction of the cart, including the wheels. Owners of bullock carts state that prosopis is a good material as long as it is kept dry. Changes from wet to dry make the wood split, which has a negative influence on the lifetime of the vehicle.

For ploughing a large (20 to 30 cm) piece of squared prosopis wood is pulled behind the bullocks to even out the rice fields after they are ploughed and watered. When preparing the soil for other agricultural crops, the fields are first ploughed and harrowed before the seeds are sown. Afterwards, the seeds are dispersed and mixed into the soil with the help of prosopis branches. Branches are cut from the fences around the fields and a heavy weight, usually a piece of solid wood, is placed on them. The branches are pulled behind a tractor that is driven across the fields in lines, covering the entire area. Farmers with smaller fields and those not owning a tractor just pull the branches behind them when walking across the field, likewise in lines. The thorns of prosopis are capable of mixing the seeds into the soil. After this operation, the branches are used as dry fencing material on the farm.

For agricultural tools, prosopis is used in various ways. The mature wood (heartwood) of prosopis is used as handles for different agricultural utensils, like shovels and hoes. Another use of prosopis among farmers is to protect mango and coconut trees from uninvited harvesters. Prosopis branches, with their sticky thorns, are bound around the stem of the trees to hinder possible thieves from climbing up the stem and reaching the fruits. They also keep animals from damaging the stem.

5.4.4. Charcoal

Charcoal is not commonly used as fuel among rural households in Andhra Pradesh. It is more frequently used in tea shops and hotels in the urban areas. In industries, where much energy is needed, like in the Raigado steel plant, charcoal made from prosopis is used in large quantities. Dobies, the Hindi name for laundries, almost always use charcoal in the process of ironing. The irons used in India are made of heavy metal and charcoal is put inside to heat up the iron plate. On average, an iron that is used the whole day for eight to ten hours consumes approximately seven kg of charcoal. On average, one kilo of charcoal costs five Rupees. The handle of the iron is made of prosopis because, according to a manufacturer, it is easier to drill a hole through prosopis wood than through *A. nilotica*, the other alternative species for this purpose. Laundries are found all over India in huge numbers, which creates a high demand for charcoal.

Charcoal is produced by burning prosopis wood in "bati" formations (the local name for the kiln used). Batis are arrangements of the wood in round circles with a top layer of coal dust that is sprinkled with water (Figure 16). The whole process, from first forming the "bati" to the final loading of the charcoal onto lorries, takes around two weeks. The burning process itself requires between 5-8 days and needs to be carefully guarded to avoid an excessive flow of air into the kiln. Too much air would provoke an open fire, thus burning the wood instead of transforming it into charcoal. One bati consists usually of approximately 60 tons of fresh prosopis wood, which produces 15 to 16 tons of charcoal. According to the craftsman, it takes approximately four kilograms of fresh prosopis wood to produce one kilogram of charcoal. The processing site in the Nalgonda District sells 40 to 50 tons of charcoal monthly, mainly to industrial plants and in smaller quantities to charcoal wholesalers or restaurants.

The charcoal burning process is managed and guarded by an employed family that usually lives at the burning place. This was the case in all three sites visited. Extra workers were employed, to unload the wood and arrange the bati, as well as for loading the transferred charcoal. The charcoal enterprises are owned privately and situated outside towns in areas where prosopis is abundantly available. Because of their high energy content, prosopis roots are preferred for charcoal production. Whenever land is cleared, for example for real estate properties or building projects, either manually or in most cases with the help of excavators, prosopis roots are dug up and sold to processing sites. The conversion of wastelands covered by prosopis into eucalypt plantations also produces root material. Since roots do not need to be chopped into specific sizes, they are traded for 500 Rupees per ton. Other parts of prosopis wood demand the same price of 500 Rupees per ton but the wood needs to be cut into sizes that are suitable for the construction of a bati. For cutting the wood into suitable sizes, extra workers are needed, and these wood cutters demand a payment of around 200 Rupees per ton.

The investigation revealed that a-medium sized charcoal enterprice converts approximately 240 tons of prosopis into 40-50 tons of charcoal monthly. The wood costs for the entrepreneur vary between 500-700 Rs per ton, depending if the wood needs to be cut into suitable pieces. The market price for one ton of charcoal is 5,000 Rs. Calculating the monthly income of a middle-size charcoal enterprise reveals that, after the expenditure for the prosopis wood, there is a monthly net-income of 81,000 Rs. In addition it creates work for several people, including wood cutters, wood collectors and lorry drivers who transport the wood to the production ground and the charcoal to different wholesale places.

Figure 16. Charcoal burning in progress.
Processing a "bati" kiln with prosopis wood in front and prosopis trees in the background.
(Photo: Kurt Walter).

5.4.5. Wood purchasing enterprises

In the rural regions of Andhra Pradesh, it is common that household members take care of collecting and cutting prosopis for their fuel requirements. It is rather uncommon to find any enterprise in the villages that sells firewood. In urban areas, on the contrary, prosopis is sold by small family enterprises that include three to five male workers, depending on the size of the venture. On the outskirts of Hyderabad, an estimated 300 trucks loaded with mainly prosopis wood gather daily at determinate places during the night hours from 3 o'clock onwards to sell their loads to the small-scale firewood enterprises. Those lorries arrive there from a range of 100 to 200 km where the wood has been collected from farmers and other labourers. Each truck contains an average of 10 tons of wood, which is sold within a few hours. The local dealers need to cut the wood into suitable pieces, according to the demands of the customers, and sell it by weight measures. The wood shops are usually situated close to the places where the trucks arrive, saving further transportation costs and effort. Competition among different wood dealers is tough, which keeps the prices relatively low for the customers. At the same time, the profits for the entrepreneurs are also relatively low for a work that requires high physical input. The wood sellers buy prosopis

as a whole truck load for 1,250 Rupees per ton. After cutting the wood into pieces suitable for burning, they sell it to customers for 1.50 Rupees per kilo (15,000 Rs per truck load of 10 tons).

In smaller towns, prosopis is purchased at a lower price than in the metropolis of Hyderabad. Outside the city of Rajahmundry, the wood wholesaler buys prosopis already chopped in suitable pieces for 800 Rupees a ton and further sells it to his customers for 1.000 – 1.200 Rupees per ton, depending on the season. Particularly, during the agricultural off-season, i.e. between January and April, prosopis wood is offered abundantly, which lowers the prices (Table 24).

In the outskirts of other major towns in Andhra Pradesh, prosopis firewood is delivered by tractors straight to the wood-selling shops. Usually, one or two workers are engaged in cutting the wood into suitable pieces to be sold in small quantities, mostly between five and ten kilograms. According to the labourers who cut prosopis, it is the most difficult wood to handle when compared with other species. Black thumma (*Acacia nilotica*) is easier to cut and also more preferred by the customers. The price of black thumma is slightly higher, and its availability is limited compared to prosopis.

Outside the town of Karimnagar, a wood seller was having fun when he watched the researcher writing up the notes during the interview. He obviously was not very fond of prosopis wood. When asked why he was smiling during the interview, he commented:

> *"..I could have not imagined that one can ask and write so much about a useless tree like prosopis. There is no other use of this English thumma than as firewood."*

Although prosopis provides the main income for the small wood enterprise, the owner did not appreciate the tree very much. He called prosopis "English thumma", while at other occasions it was called "forum thumma", literally meaning foreign thumma, expressing the origin of the tree from somewhere outside India.

Table 24. *Prosopis* firewood trading prices.

Enterprice type	Wood-cutter price (Rs/ton)	Middlemen price (Rs/ton)	Consumer/market price (Rs/ton)
Wood sale enterprise (Hyderabad area)	700	1,250*	1,500
Wood sale enterprise (smaller towns)	600	800**	1,200

* Price for wood sellers who buy the whole lorry load.
** The difference of 200 Rs is the wage for the worker who cuts the wood into suitable pieces.

5.4.6. *Prosopis* as a source of industrial biofuel

On a large scale, prosopis is used as a raw material for biopower plants. The Jyothy biopower plant is one of the 25 to 30 existing bio plants in Andhra Pradesh that contribute annually 200 megawatts of electricity to the state. The Jyothy plant started its production in the year 2000 with a capacity of 4.5 megawatts and increased its productivity to 10.5 megawatts in 2003. The plant is working on

100 per cent agricultural-based biomass, of which 40 percent consists of prosopis. The monthly estimated amount of prosopis wood is 4,000 tons. Another 40 per cent of the fuel supply comes from eucalypt plantations and the remaining 20 per cent consists of crop residue and other agricultural waste material.

The plant was established in the Prakash District, 10 km outside the city of Ongole, because of the dense occurrence of prosopis. While the price for one ton of prosopis wood was 500 to 600 Rupees in the year 2000, it had reached an average price level of 1,000 to 1,200 Rupees per ton in 2005. The fuel supply is organized by contractors who buy and collect prosopis from the people within a range of 100 km from the plant. The wood is collected with bullock carts or tractors to determined assembling places and from there loaded on trucks, which transport the loads to the plant. The price of prosopis wood fluctuates depending on the season. The contractors, who are the middlemen between the power plant and the small enterprise wood cutters, pay an average of 700 Rupees for one ton of prosopis wood. The wood needs to be cut into a suitable size according to the requirements of the bioenergy plant.

The general manager of the Jyothy biopower plant, Mr. T. Ramakrishna, explained that according to the company's own research, prosopis contains heat energy of 3,800 – 4,000 kcal/kg while the values for eucalypt wood reaches about 3,200 kcal/kg, which makes prosopis an appreciated source of fuel (Table 25). Compared to eucalypts, the cheaper price for prosopis makes it a prefered raw material.

Table 25. Jothy biopower plant energy.

Jothy biopower plant	
Capacity of the plant	10.5 megawatt in 2003 (4.5 megawatt in 2000)
Fuel	100 % biomass
Fuel components	Prosopis → 40 % Eucalypts → 40 % Crop residuals → 20 %
Fuel energy (bioplant research)	Prosopis 3,800-4,000 kcal/kg Eucalypts 3,200 kcal/kg
Consumption of wood/ month	Prosopis → 4,000 tons Eucalypts → 4,000 tons

The *panchyats* of the region near the power plant auction the prosopis stands that grow on wastelands and sell them to the highest bidders. The leaseholder then either employs labour that cuts and collects the trees or rents out the acquired lands to interested parties who cut and sell the wood as their own undertaking. The common rent for the trees is 500 Rupees per ton and the labourer is able to sell one ton for 1,000 Rupees if sold straight to the end user. The wood can be

sold to the power plant or to the brick industry according to demand. To extract one ton of prosopis takes two days for two workers. During the crop season, when there is a shortage of labour for tree cutting, the price for prosopis wood rises to 1,200 Rupees per ton.

The medium net-income for a prosopis wood cutter, who pays rent to the landlord in order to cut the trees and sell the wood on his own behalf, is on average 50 to 70 Rupees per day. It is common that the leaseholder employs a helper who will be employed occasionally according to the demand for prosopis wood. Those labourers, whose income depends entirely on cutting and selling prosopis, are not able to cover their monthly life expenditure on this income. They do not find work throughout the month unless they are not living close to a plant that consumes prosopis in significant amounts. Commonly, their wives are employed by farmers during the crop season in order to support the economy of the family. In poor families even children are employed to do farming work during the season instead of attending school. According to the labourers, wood cutting with primitive small axes is very hard work. Doing the work in the same way as it is done by the local labourers convinced the researcher about the tough physical labour needed to cut and chop prosopis trees. One of the wood cutters indicated that it is common among his colleagues to drink toddy, wine made by tapping the sap from coconut or sugar palm inflorescences, after finishing the daily work. He spends half of the earned money for drinking toddy in order to get relief from his body pain. The other half goes for the family's expenditures.

Other industrial power plants

The Tirumala Solvind Industries PLVT Company produces edible oil from sunflower seeds and groundnuts. The raw material for processing the oil comes from virgin pressed sunflower and groundnut cakes. The sunflower cakes contain 12 per cent oil (fresh seeds contain 32 percent) and the groundnut cakes seven to eight percent oil (fresh nuts contain 32 to 40 percent). To generate the heat that is needed for the oil extracting process, prosopis is used exclusively. The medium-sized enterprise, with approximately 50 employees, needs six tons of preferably medium sized (5 to 10 cm diameter) prosopis wood daily for the procedure. The company buys prosopis wood for 900 Rupees per ton. It competes with the nearby biopower plant for the raw material and from time to time faces shortages of the resource.

There are a number of chemical plants in the Rayalaseema region that use prosopis as fuel for generating the heat needed for their production processes. Outside Caddapah, one enterprise produces sodium sulphate, transferring it from a solution to a solid phase, while another industrial plant is specialized in the production of sodium and barium carbonate. This company uses 40 tons of prosopis fuel daily while the nearby Cuddapah Tyres Retreading Company uses 15 to 20 tons per month. All the above-mentioned enterprises suffer from shortages of prosopis wood during the agricultural season when wood cutting activities are low. According to the management of the industries, prosopis is the cheapest fuel resource available.

5.4.7. The brick industry

Prosopis wood is commonly used to produce the heat needed for the manufacturing of bricks. The wood that is used for the burning process consists mainly of prosopis that is supplied by surrounding farmers or landless labourers. Prosopis is a relatively cheap raw material when compared to other sources, like the mineral coal or charcoal used in previous years, and it is always available. The entrepreneurs pay an average of 600 Rupees per ton for prosopis wood that they buy straight from the wood cutter. During the agricultural season, when there is a shortage of wood cutters, the price for one ton can climb to 900 Rupees. Prosopis roots are also used, and even preferred for the burning process since they are high in energy content. Clay, the raw material of the bricks, is pressed to form and dried. The bricks are then piled up in a square closed at the top, leaving entrance holes at the bottom of the structure. Those openings are then fed with prosopis wood to burn the kiln from inside.

Figure 17. Baked bricks with *Prosopis* roots used for the burning process.
(Photo: Kurt Walter).

A typical brick burning kiln (cf. Figure 17) consumes a total of six tons of prosopis during its two-day burning process. A medium-size brick factory consists of five to ten workers with a fuel use of 8 to 18 tons of prosopis wood per month. Husks from agricultural crops are used in addition to prosopis for the burning process. The labourers are paid according to the number of bricks they produce. The salary for a thousand bricks is 130 Rupees. With one ton of prosopis fuel, the factory is able to manufacture 2,500 bricks. The owner of a brick factory on the outskirts of Tirupati employs ten workers who enable him to make an annual net profit of 20,000 Rupees.

5.4.8. Tobacco leaf drying

Andhra Pradesh produces flue-cured Virginia Tobacco (*Nicotiana tabacum*), which is suitably grown on so-called black soils. Those black soils, also known as Regurs or Vertisols, are generally associated with poor drainage. They cover nearly 25 per cent of the cultivated areas in the Andhra Pradesh districts of Guntur, Prakasam, Krishna, East and West Godavari, Khammam and Nellore. Since it is possible to receive irrigation water from the Nagarjuna Sagar Project, considerable areas in Guntur and Prakasam Districts are converted to food crops and commercial crops, such as cotton and tobacco. In order to fill the lack of tobacco production and in view of the fact that flue-cured Virginia Tobacco grown on light soils is claimed to be of better quality, this tobacco is now mainly cultivated in the areas of light soil in West Godavari, Prakasam and Nellore Districts. Sandy soils have a poor water holding capacity, which makes them unsuitable for paddy cultivation in rain-fed conditions. The sandy soil favours cotton, chilly and tobacco cultivation over other crops.

According to the interviewees, the procedures are as followed: In order to cultivate tobacco, the farmers need a licence from the ITC (Indian Tobacco Cooperation), which, on their behalf, supplies the farmer with extension services to promote the best possible quality tobacco. The tobacco harvest is guaranteed to be bought by the tobacco industry after it is processed by the farmer. Seeds of improved varieties are supplied annually to the farmers by the Central Tobacco Research Institute in Rajahmundry, its regional stations, and other organisations connected with the tobacco crop.

The flue-cured Virginia Tobacco is harvested between December and March. In the Ongole District the harvest takes place during December and January. Soon after the harvest is collected, the leaves are strung on bamboo sticks at a rate of about one hundred leaves per stick in preparation for the curing process. The curing takes place in special buildings known as barns with artificial heat passing through metal pipes called flues.

As the tobacco farmers explained, the heat in the barn is generated by stoves, usually two stoves per barn, which are situated on the bottom of the building while the leaves are hanging in the drying chamber on the upper floor. Curing takes 100 -120 hours, after which the leaves are collected from the barn, bulked for a few days and then graded, depending on the colour of the dried leaves. The amount of fuelwood needed for the four-day procedure is estimated as five tons of fuelwood for ten quintals (1 quintal = 100 kg) of tobacco leaves. The dried leaves are then stored by the farmers until the tobacco company collects the harvest according to their schedule.

In previous years, fossil coal was used as a heating material but this has become too expensive and has been replaced by fuelwood. Up to 80 percent of the fuelwood now consists of prosopis, with another 20 percent derived from tamarind and other available tree species. The price for one ton of prosopis wood varies between 700 and 1,000 Rupees according to demand and availability. It is common that the farmers buy the wood from outside sources because they usually are busy with

cultivation activities. The price the tobacco industry pays to the farmers varies and has been declining during the last few years. In 2001 the payment for one quintal of first class tobacco leaves was 7,000 Rupees while secondary quality leaves were purchased for 3,000 Rupees/quintal. In 2005 the price for first quality leaves was 4,500 Rupees per quintal and 2,500 Rupees for secondary quality leaves.

5.4.9. *Prosopis* as raw material for boats

Situated close to the seashore, about 15 km south of Kakinada, the capital of the East Godavari District, a boat building enterprise uses the heartwood of prosopis for the construction of boats. The owner of the company stated that according to his experience and knowledge, prosopis is very well-suited for the purpose of constructing boats. For use in boats, the wood is constantly kept wet, which makes it durable for up to ten years. The other option for relatively cheap raw material is the use of black thumma, which under similar conditions lasts an average of only six to eight years. However, teak is the most preferred raw material for the construction of boats. Teak wood is easy to process and it lasts much longer than other species, but it is also considerably more expensive.

Figure 18. Boat construction in Sitarampuram, using *Prosopis* wood.
(Photo: Kurt Walter).

The boat construction enterprise of Mr. Babugo produces 20 boats annually made of prosopis (Figure 18). The demand is even higher, but it is difficult to purchase the large pieces of prosopis wood that are necessary for boat construction. The price for large size prosopis wood is 2,500 Rupees per ton, which is the same as for *A. nilotica*. The raw material used for a boat (27 feet long, 3 feet 4 inches deep, 6 feet 6 inches wide, and with 29 ribs), amounts to 110 cubic feet of prosopis wood, weighing 4.5 tons. The price for a boat of this size is 40,000 Rupees. Six to seven workers complete such a boat in one week, working eight to ten hours daily for seven days.

In the area along the coastline of Kakinada, there are another three enterprises that produce boats using prosopis as raw material. Other competing boat building enterprises in the area specialize in boats made mainly of teak wood.

5.4.10. Environmental benefits

Hyderabad Urban Development Authority (*HUDA)*

The Government of Andhra Pradesh founded the Hyderabad Urban Development Authority (HUDA) in 1975 to take care of urban planning and the development of towns, especially the infrastructure and road constructions. Urban forestry in the larger area around Hyderabad is another prime area taken care of by the authority. One of the projects of HUDA where the use of prosopis plays an important role is the planting of trees alongside the newly-built roads that connect the centre of Hyderabad with the growing industrial suburbs.

The purpose of the project was to create a green environment along the roads that lead through stony areas of mainly wasteland with less greenery and nutrient-poor stony soils. Young tree seedlings that are pre-grown in nurseries are planted with dense spacing on a small stretch of land between the roads leading to and from Hyderabad and also along both roadsides. To protect the young tree seedlings from being damaged, they are encased in metal grids. Inside the grids towards the top, prosopis branches are fixed to protect the seedlings from being eaten by animals (Figure 19). Prosopis is easily and abundantly available for this use because it already grows along the roads on the stony wastelands that cover the landscape.

Birds breeding on Prosopis

The Uppalapadu bird sanctuary is located in Guntur District, 7 km from Guntur town. The water tank on the edge of the village Uppalapadu is unique since they provide refuge to more than 30 migratory bird species throughout the year. Endangered species, like Spot-Billed Pelican (*Pelecanus philippensis*), Painted Stork (*Mycteria leucocephala*) and White Ibis (*Threskiornis melanocephalus*), have shifted from Nelapattu in the Nellore District to Uppalapadu to breed on prosopis trees and bushes. The water tank is surrounded by dense prosopis tree and bush formations and the small island in the middle of the tank is totally covered with prosopis. According to the guard of the sanctuary, it is estimated that the bird population of these water tanks amounts to 7,000 and the number of birds stopping in the sanctuary during the peak season between September and February amounts to 20,000. Some migratory birds, like Rosy Pastor (*Sturnus roseus*), travel hundreds of kilometres to come to the sanctuary. The villagers have agreed to keep this tank only for the birds while using other ponds nearby for their needs. The unique aspect of the place is that the birds can be spotted throughout the year in this small four and a half acres stretch of land.

Both services provided by prosopis outlined above appear on a rather small scale compared with the otherwise large impact of the tree on the environment. However, they indicate how during the decades of the spread of prosopis in the arid regions, people as well as nature have taken advantage of the alien plant.

Figure 19. Use of *Prosopis* to protect young tree seedlings from being damaged by animals. (Photo: Kurt Walter).

5.5. Invasiveness of Prosopis

After the introduction of prosopis, one and a half centuries ago, the tree has naturalized itself in Andhra Pradesh. The use as live-fences on a large scale was intensified during the 1970s. In a store selling crop seeds outside the town of Rajamundry, prosopis seeds are offered for the price of 80 Rupees per kg. At the time of this investigation, the monsoon had not yet started, which kept the price for the seeds relatively cheap and the demand still low. The salesman indicated that some years ago the demand for prosopis seeds was high and he could sell one kilo for 200 Rupees. According to his knowledge, there are still many farmers who use prosopis seeds frequently in order to establish live-fences. The seeds are relatively cheap and the fences are easy to establish. Once the seedlings start growing, they do not need any special care anymore.

The fields under agricultural production with sufficiently fertile soils are generally privately owned and under intensive cultivation. The farmers do not allow prosopis to grow into the fields but pull the seedlings out in the very early stage of growth. Whenever the prosopis fence starts shading the crops, it will be pruned to allow an optimal supply of solar radiation for the crops.

However, there are situations when prosopis starts invading the agricultural fields. In the Telangana Region in northern Andhra Pradesh and in the very dry regions around the Anantapur District of Rayalaseema, the monsoon did not bring sufficient rains from 2000 until the beginning of the monsoon in 2005. During those years of rainwater shortage, farmers were sowing their crop seeds at the onset of the annual monsoon. However, the rain soon stopped and the seeds sowed on unirrigated fields rapidly dried out before they could grow. As a consequence, the farmers needed to wait for new rain to repeat the sowing of new seeds. In the worst case, it took three sowing attempts to get the seeds growing. This was only possible for financially better-off farmers who were able to pay for the seeds that became more expensive after every attempt due to shortage of supply. In some extremely drought-affected areas in the region of Rayalaseema, the following year brought droughts again and with still increasing prices for seeds, many farmers were forced to abandon cultivation and leave their fields fallow. As a consequence, prosopis that had been managed and kept as fences around the fields started to invade the crop fields.

Outside the town of Karimnagar, in the Telangana area, a farmer who was preparing his field for cultivation and pulling out prosopis shoots, told us that he was one of the victims of the frequently occurring droughts during the last few years and was not able to cultivate his fields. Now he needed a lot of efforts and working hours to get the fields cleaned from the invading prosopis shoots. He needed to sell his livestock and still get an additional loan in order to buy new seeds for the coming season. He was aware that continued droughts with insufficient rains during the monsoon will cause an invasion of prosopis into the uncultivated fields and that it will be difficult to get this invasion under control.

The close proximity of the two main rivers in Andhra Pradesh, the Godavari River and the Krishna River, makes irrigated agriculture possible. The irrigation canals are commonly densely covered with prosopis. There have been attempts from the Agricultural Department to eradicate those trees from the banks of the canals but without any major success. Very soon, after a year or two, prosopis again inhabits the newly cleared space. Farmers expressed their worries that the invasion of the tree is affecting the flow of water in the canals.

The *sarpanch*, or head of the village, reported in the interview that only a decade ago, it was possible to cultivate and harvest rice twice annually without irrigation. The recent droughts have made only one harvest possible, and only farmers who had the financial resources to continue

cultivation after a failure in sowing were able to get at least some kind of income. Many others had to sell their livestock to be able to maintain their livelihood. He had been told by many concerned villagers that prosopis has invaded their fields that have been left fallow during the drought period. The *sarpanch* was concerned about this development and thinks that only continued cultivation and care of the fields will prevent a major invasion of prosopis in this drought-affected region.

In the rural areas of Andhra Pradesh, it is typical that a natural or man-made water tank/pond, is situated at the entrance to a village. These water reservoirs are part of a traditional way of harvesting rainwater and are meant to supply the village with water for agriculture and drinking. They are also used for rituals and religious bathing. Most of these ponds are heavily invaded by prosopis, which makes it difficult for the animals and people to penetrate the thickets in order to reach the water. Villagers believe that prosopis has spread with sheep and goats that contain the seeds in their faeces. The *sarpanch* of the Buchanpeta village in the Kakinada District said that two years ago the village started a campaign to eradicate prosopis from around the pond. During the summer, after the harvesting time was over, they succeeded in cutting down all the trees and digging out most of their roots. Despite this effort, after only two seasons young prosopis trees were growing all around the pond again.

One of the villagers put it this way:

> *"...this tree is immortal. Today you cut one, next year you find two of them in its place".*
> (Villager talking during group discussion).

As already implied in the name given to prosopis, "sarkar thumma", or government tree, it grows commonly on wasteland, which is generally owned by the government. One of those wasteland areas where prosopis has spread exceptionally heavily is alongside the railway tracks. Those places, especially in villages with poor infrastructure and in town quarters close to the railway station, are widely used as toilets by the local people. Prosopis thickets give people a welcome shelter for this purpose, which is especially appreciated by women because for them it is important not to be seen when performing their natural needs. A railway official in the town of Narasaraopet indicated that the railway authorities have plans to eradicate prosopis along the trail in order to renew and expand the railway system.

According to Dr. Ramana Murthy, the Conservator of Forests of the National Forest Department in Hyderabad, there has not been any research done by the Forestry Department that provides scientific data about the invasion of prosopis in Andhra Pradesh. Dr. Murthy said that the Forestry Administration has received several complaints from farmers during the last few years about prosopis invading their crop fields. According to his knowledge, the only project initiated by the Forestry Department was to plant prosopis along the highway in an area in the Kornool District. The shelterbelt was aimed to establish a green area between the traffic road and the fields and to stabilize the soil of the slopes that lead to the fields. He was not aware of any other project where prosopis was planted deliberately and initiated by the Forest Department. Dr. Murthy also did not have any knowledge about the results of the shelterbelt project since no evaluation was done afterwards.

On the roadside of a highway leading into Tirupathi, labourers were cutting prosopis along the National Highway. They were employed to cut prosopis, keeping a distance of one metre between the asphalt and the bushes and trees because the plants were beginning to narrow the space for

traffic. The slopes were also cleaned and prosopis trees, along with their roots, were pulled out of the soil. The trees were cut and left beside the fields and people were allowed to carry them away for firewood without any charge.

As stated by the Chief Conservator of the National Forest Department, Mr. P. S. Rao, the Irrigation Department is organising work to eradicate prosopis alongside the irrigation canals. Prosopis was originally planted to stabilize the banks of the canals and to prevent them from erosion. However, the tree has invaded the banks in dense thickets and is growing roots inside the canals. This slows down the flow of water and, additionally, hinders operations to clean the canals from silt because it is impossible to place the excavators close to the water streams.

While travelling through the state of Andhra Pradesh by train, bus, or car, one can easily notice the extent of the prosopis invasion, and it becomes obvious that the tree has come here to stay. Places with dense thickets of prosopis bushes are found especially along the railroad, on wastelands, and on riverbanks (Figure 20). Dense formations of prosopis thickets are growing near all water sources because the availability of water enables prosopis to out-compete any indigenous plants. In the coastal areas, where soils are saline, hardly any plant other than prosopis is visible on the large strips of the coastline. People living there have learned to use prosopis very efficiently and almost every household is involved in cutting or selling prosopis.

Prosopis is still widely perceived as a natural resource and people do mostly benefit from it. Nevertheless, there are already high costs involved in eradication efforts where the tree is not desired. The Department of National Highways spends huge sums of money annually to clean the roadside of prosopis.

Professor T. Pullaiah, a leading taxonomist in Andhra Pradesh at the University of Anantapur, believes that the reason for further unlimited invasion of prosopis lies in the fact that the tree is not facing predators, pests or diseases as it does in its natural indigenous surroundings in Central America and the Caribbean. He also stresses the high germination capability of prosopis that encourages a further rapid invasion of the tree.

Figure 20. River bank invaded by *Prosopis*.
(Photo: Kurt Walter).

5.6. Hindu classification of trees[12]

5.6.1. Clasificationi of sacred trees

For Hindus, trees, forests and all of nature is a living entity, a part of god's creation that has a soul. Nature is however ranked. The top ranking trees, such as the bodhi, banyan and *nāgaliṅga* trees, are not utilized except the flowers of *nāgaliṅga* for *pūjās* and in rare cases leaves of the bodhi and banyan trees for medicinal purposes. They are believed to be the residences of deities and are found in many temple gardens. Neem trees are also believed to be abodes of female deities, especially *Amman*.

On the second level of classification of trees are those species that are highly beneficial to people but not necessarily abodes of gods. However, at the village level they may be regarded as the residence of village deities where *pūjās* are celebrated. Banana trees (*Musa* spp.), sugar palm trees (*Borassus flabellifer* L.) and coconut trees (*Cocos nucifera* L.) are trees that rank on a slightly lower level. Those trees are usually intentionally planted and taken care of by the farmers who own them. Illuppai (*Madhuca longifolia* (J.Konig) J.F.Macbr.) trees are also regarded as sacred. The species is called the Indian butter tree; it provides delicious and nutritious fruits that can be stored for long periods of time. Its bark is an important source for medicines used to cure leprosies and its flowers are prepared to relieve heart disease and cough. Although the wood is moderately hard and durable, it is only seldomly used to make furniture because its sacred status makes people reluctant to cut down the trees and utilize the wood.

Banana trees (technically not trees but giant herbs) are of utmost importance to people because of their multiple benefits. Besides the fruits, which are a nutritious and important food all over the world, all other parts of the trees are used also. In the research area, food was served on a banana leaf. After the meal, the leaves are recycled by the cows that come to eat them behind the restaurants. The leaves of banana trees are dried on the fields, covered with soil so that they straighten and can be used to thatch roofs. Well-dried and prepared, they keep the rain out of houses for one year, after which they have to be renewed. There is no marriage in South India without a banana tree in front of the ceremony hall. It is a sign of auspiciousness and fertility. The banana tree is also often used in marriages between humans and trees.

The third level in the classification of trees contains commercially important tree species that are grown in plantations. Although not regarded as sacred, they are valued for the monetary income they provide to rural households. In the first place, teak wood is mentioned as a most valuable economic resource. Teak wood is valued in the building and construction industry and is the most appreciated raw material for making furniture. It is also a lucrative commodity for the export sector. Various species like poplars, casuarinas and eucalypts, are also appreciated as commodities that can be easily sold and bring a relatively solid income to the farmers. While teak plantations have a 25-year rotation, eucalypts and casuarinas can be harvested and sold already after five years. In addition to the species mentioned above, several fruit trees grown in orchards or home gardens are classified as being important without having a particularly sacred status. Those trees supply fruits like mango, tamarind, papaya or drumstick.

Trees that are least honoured and respected by people are those that are not sacred and have no immediate economic value. Most interviewees placed prosopis into this category. Although used for

[12] This general information, as reported for India by anthropologists (e.g. Nugteren 2005) and other observers, was confirmed by the field observations and interviews reported here.

so many purposes and by so many people, prosopis has low value and is not very much respected, in comparism with indigenous trees. Firewood and fencing material are the uses that come into peoples' minds when asked about the usefulness of the tree. When people talk about prosopis, they seldom fail to mention that the species is foreign to India. The thorns of prosopis cause injuries, and people try to avoid getting into contact with the tree if they have the possibility to use other species.

Many tree species can be added into the above categories and some farmers might shift one or the other tree from one category into another but the basic classification remains the same. In the case of the sacred trees, all those mentioned have been classified as sacred by everybody, without exception. There are instances where the choice of a tree to be worshipped does not adhere to the ranking system because the selection of it does not follow any rational pattern. Even prosopis that often has been described as a useless tree can gain sacred status, as the later examples confirm.

5.6.2. Veneration and status of sacred trees

Religious rites in India are often performed in the context of trees. The life of a Hindu contains obligations to perform rituals during the entire life cycle. Some rituals need to be performed daily, while others occur in connection with important personal or communal rites, like marriage or the annual celebration of the village deity. Tamil Nadu is known, especially, for its numerous tree rituals. For that reason, the information for this section was collected in the rural areas around Kumbakonam in Tamil Nadu.

In the villages of Tamil Nadu, the belief that certain trees are chosen by various deities as their abode has existed for generations. Those deities are either female or male. People believe that male gods protect the villages from evil spirits while female goddesses are enshrined because they help women bear children. People hope that the fertility in trees is a quality that will be transferred to humans. Tribal groups in the villages also have their specific temples and trees at which they gather to perform their religious rituals. Demons are also believed to choose certain trees as their residence.

As reported from other parts of India, the people interviewed spoke about their deep respect towards trees because of the many benefits they receive from them, from fuel and construction wood to non-timber forest products (NTFPs), such as medicines and fruits. Trees provide food even in time of scarcity. Trees such as bodhi or banyan are classified as most sacred and are protected by the village communities, although their leaves might be used as fodder. In the present study, the provision of shade for people and animals was often emphasised as one of the most appreciated amenities that trees provide. Shade is highly important particularly in these areas with temperatures that can reach between 40° and 50 °C.

The interviewees saw the irregularity of the monsoon rains as the cause behind the depletion of the tree cover during the past years. Many of the interviewees were of the opinion that trees attract clouds and rain, and since there are fewer trees around, the climate has changed to the detriment of the farmers. Others were eager to admit that in addition to the vanishing tree cover in the region, other facts like air pollution effect climate change, but as they state, the fact remains that the monsoon rains are nowadays delayed and irregular.

Some sacred species, like bodhi or banyan, are not utilized because it is regarded a great sin to fell or even cut branches of them. It would be difficult to get any labour for cutting down a sacred tree

because no one wants to anger the deity who lives in the tree. However, there are some species which are utilized for their timber, as in the case of the neem tree.

The indigenous neem tree is one of the sacred trees that can be found all over India, in villages and out in the fields. If neem trees are intentionally planted and grown for the purpose of utilization, the owner of these trees may prune and fell them to be used as building material. The wood of neem trees is appreciated for the construction of door frames and ceilings. The interviewees pointed out that there are natural pesticides in the wood that make it preferable as a raw material for construction. However, as mentioned, neem wood is never used as thresholds because it is too sacred to be stepped on. The wood is also not used for funeral pyres because of its sacred status.

More or less, every part of the neem tree, including seeds, leaves, roots, bark, trunk and branches, are used for various purposes, especially for the preparation of medicines. One of the most important inherent qualities of the tree is related to its antimicrobial effects. The ancient medical sciences of *ayurveda* and *siddha* make use of these qualities when using the essences as medicines. The use of the neem tree to produce remedies for ailments remains very common among the rural people today. While some villagers use a medicine when it is prescribed by the local *ayurveda* or *siddha* doctor, others use it without seeing a doctor because it has been applied for various diseases in the family for generations.

In the present study, the villagers indicated that if one is having a non-vegetarian meal outside one's home, for instance while working in the fields, it is important to carry neem leaves to keep evil spirits away. Demons can easily smell the animal blood contained in the meat and may harm the person eating a non-vegetarian meal. The neem leaves create a natural shield from these negative forces.

It was indicated also that neem oil, which is extracted from various parts of the tree, especially the seeds, has been used for the cure of smallpox. During the British colonial period, it was compulsory to hang neem leaves outside the door of every house where smallpox had appeared. Families who were not eager to be visited by government officials placed neem leaves outside their doors to make sure that no officials would enter the house. Various skin diseases are treated with cream produced from boiled and pounded neem leaves, and one often encounteres the sight of the green-coloured faces of women or children who have applied those medicines.

As mentioned above, the most sacred tree in India is the bodhi tree, the tree under which the Buddha is claimed to have found enlightenment. There was barely any bodhi tree in the villages around Kumbakonam that was not marked and decorated with sacred ornaments. Usually bodhi trees are associated with temples or shrines. People explained that, as a rule, the tree first appears in the place and the temple is built only afterwards. In addition to bodhi trees, an ancient temple might consist of a variety of tree species of many generations, including trees that grow on the place of an already decayed one. In the research area, the banyan tree occupied an almost equal place to the bodhi tree in the classification of the most sacred trees. In the rural areas of Tamil Nadu, banyan trees appear in significant numbers. It was indicated by villagers that it is the magnificent size and beauty of the banyan tree that attracts both deities and devotees. Both fig species are usually found near running water. The huge size that these trees achieve requires large quantities of water to keep them alive. Water is also important for the devotees to perform the personal cleaning procedures required to participate in the *pūjā.*

Because of the huge size they reach in mature age, and, thus their high requirement of water, bodhi and banyan trees are usually not grown on or near agricultural lands. Huge trees of both species,

however, are usually found in central locations of the villages, in such common places where people gather to rest under shade and make conversation with each other. Both species are common property that belongs to the whole community. Leaves of both trees might be used for the production of medicines, but only on a small scale that, often, needs to be accepted by the community.

During the investigation, one of the interviewees informed the researcher about an incident that had just happened to a farmer who owned the land behind a temple for *Muneeswaran* (the male god of bravery) who was claimed to reside in a huge banyan tree in the temple yard. The tree had grown to an immense size and started casting shade over parts of his crop field. So the farmer cut off the branches that reached into his field. The interviewee, who was the caretaker of the temple, indicated that:

> *"..Muneeswaran was so angry with the farmer that he sent him a terrible sickness. Now the landlord regrets what he has done but it is too late. According to the doctors, he will soon have to die. We villagers had told him to restrain himself from doing any harm to the tree but he would not listen to us".*

The cannonball tree, or *nāgaliṅgam* (*Couropita guianesis*), is indigenous to Guiana in South America but can also be found in India, where it is named Shiv Kamal (or *nāgaliṅgam* tree), and is considered a sacred tree. The flowers that the *nāgaliṅga* tree produces are the reason behind its sacred status. The beautifully shaped stamens in its flowers have the form of a snake (Sanskrit: *nāga*) with a *śivaliṅgam* (symbol; representation of *Śiva*) at the innermost centre. The tree flowers twice a year and the flowers, which are also appreciated for their fragrance, are used in *Śiva pūjās.* The interviewees indicated that the two *nāgaliṅgam* trees in the yard were planted by a Brahmin family that used the flowers for their own home temple. After the family had left, priests and devotees from other temples come and collect the flowers for their own religious ceremonies. Farmers are reluctant to plant *nāgaliṅgam* trees because these are not allowed to be felled and there is no use for them other than as ornaments and offerings in religious ceremonies. Now the tree has become rare and is in need of protection in India. It is nowadays the responsibility of the temple community to grow this tree with the aid of a government fund that is available for the support of religious practices.

5.6.3. Tree marriages

In South India, tree marriage is an ancient cultural and religious ritual that is still commonly practiced today. Trees are married with each other (Figure 21) and also with humans. In marriages between trees it is usually the neem and the bodhi trees that form a union. People believe that as humans need life-long partners in order to lead a fulfilled life, so also trees should not live alone.

There are different types of tree marriage. The seedlings of a neem and bodhi tree may be planted at the time of the wedding of a human couple. First the bride and groom tie a yellow coloured *thaali* (sacred yellow thread) around both tiny stems as a sign of the union. The guests of the wedding are brought together to watch and bless the ceremony. Afterwards, the marriage of the human couple takes place when the groom ties a *thaali* around the neck of the bride. It is believed that the tree marriage will bring good fortune to the couple and the virtues of those trees will be transferred to

the life of the family. The hope for children is expressed, especially, during the *pūjā* celebrated in honour of the trees.

Figure 21. Sacred union of a bodhi (left) and a neem tree (right) planted and married as seedlings.
(Photo: Kurt Walter).

The wedding of two trees need not be performed on the same day as the human marriage although it is often practised this way. It can be done also some time before the human couple gets married. In that case it means an additional celebration for the villagers. This is believed to be another motivation why couples are encouraged by the village community to perform tree marriages. For the couple it is to make sure that they get the gods' blessing for their future life; for the community it is a reason to celebrate. The following story was narrated by a 76-year-old man at the site of a bodhi tree that was decorated with a small *Śiva* temple at the foot of the trunk. At the side of the bodhi tree the dry stem of a neem tree was still visible, as if growing out of the bodhi tree. The man lived with his son, daughter-in-law and grandson in a small house opposite the tree. Here are his words (translation from Tamil):

"…in the summer of 1953, I planted the bodhi tree opposite of my house, long before the street was built. After I had seen in many places that bodhi trees have been planted together with neem trees, people told me to do so as well to please god. I did as advised and planted a neem tree right beside the bodhi tree. When my parents decided about my marriage and chose a wife, I was advised by the elders of the village and relatives to first perform the tree marriage ritual as it is done in our region, before marrying my future wife. It was believed to grant me an auspicious family life and many children. I organised the pūjā, *tied the yellow* thaali *around the trees and ritually performed the wedding between the trees. The same day the whole village was invited to celebrate at my expense.*

I finally got married to my wife a short while later and she delivered our first and only son soon after. We spent ten happy years together, when my wife suddenly became ill. At the same time, during which my wife went through a serious sickness, which ended in her death, the neem tree started to become dry and finally died, together with my wife. I think our life and her departure were directly connected with the life of those trees. I did not marry again, because whenever I look out of my house to the trees opposite, I feel that I am still connected with her in the same way as the neem tree, although now dry, is still connected to the bodhi tree."

While telling his story, tears were running down the cheeks of the old man. With his son, he maintains and cares for the temple, consisting of the statue of a deity and vessels where devotees light camphor oil for the sacred fire (*āratī*), in front of the trees. People passing by often stop for a prayer, and from time to time the family organises *pūjās* with many participants from the nearby neighbourhood.

A different reason for a marriage between trees and humans is connected with astrology. The interviewees explained that in the traditional Indian marriage, where the parents choose the bride or groom, an astrological chart will be ordered to see if the constellation of the stars permits a harmonious life for the couple. In case the astrologer finds any misfortune, like the sickness or death of a child in this marriage, the choice to marry a tree first is made to avoid the bad fortune of the couple. The woman or man, whoever is the one with the bad omen, gets married with a tree, which is then her/his first marriage. After the ceremonial wedding, where the bride or groom ties the *thaali* to the trunk, the tree will be cut, which symbolizes the end of the first marriage. The second marriage between the couple, that is now free from the bad omen, will be performed during the same day. Some of the villagers still remember the last time this kind of marriage was performed in the village. The bride was married to a banana tree and the tree was cut down after the ceremony.

Nevertheless, the most sacred union between trees is when it happens through natural distribution. In many temple yards, it could be observed that neem trees grow out of the branches of bodhi trees, probably through bird dispersal of the seeds. For Hindus, this is a most sacred union. In one of the sacred groves visited, the *pūjārī* indicated that women started coming to him with the request of getting children. *Amman*, the godess who resides in the neem tree nearby, contacted him while he was in a state of meditation. She asked him to find a tree that served as a host for a neem tree growing out of its branches. After searching for some time, he found such a sacred union and was instructed to collect some branches from the neem tree. *Amman* then guided him to place the bundle of neem leaves on the head and shoulder of the devotees who should meditate on the godess. He explained that after that, many of the petitioners have delivered children and come back regulary to

this place to pray and thank *Amman*. This is visible through the many saris (Indian traditional womens garment) and ornaments that are hanging from the branches of the temple trees.

5.6.4. Trees as places of worship

The Tamil people in South India practise many rituals connected with trees. There is no Hindu temple in South India, which does not have trees in near proximity. The trees are usually those species that are regarded as sacred among Hindus. Many smaller temples may consist of a tiny altar, made of a statue out of stone representing a deity or a *Śiva liṅgam*, a symbol for the Hindu god *Śiva*. Several larger temple complexes have their origin in tree altars that have expanded due to the increasing number of worshippers.

The selection of a particular tree to be worshipped happens usually through village women who are known to possess special spiritual capabilities. However, in rarer cases men are contacted by the deities or spirits. The god or goddess reveals the tree to be selected as a residence to the chosen devotee during a state of trance where she or he is susceptible to meet the spirit or deity. Those selected trees are frequently visited by devotees who offer prayers and perform rites in honour of the deity. In response, the deity will take care and protect the village from bad spirits, demons and natural disaster. In many cases, the selected tree is one of the species that are classified as sacred among Hindus. However, exceptionally, even prosopis trees have been selected as abodes of deities.

Banyan trees are found all around Tamil Nadu and their magnificent size and aesthetic beauty were mentioned as virtues that attract people. The ashes of the deceased are often burried under banyan trees, which become places of worship. The wish for offspring frequently activates female devotees to come and pray under the shade of banyan trees. Interviewees also explained that people associate the growing pattern of banyan trees with human development. The aerial roots, typical for the growth of banyan trees, descend from the branches and attach to the ground to support the heavy branches. Devotees express their hope that, likewise, in their life their children will support them when they become old.

It is most common to find the trunks of banyan trees decorated with silk saris and small cradles hanging from the branches. These miniature childbeds are the way for many women to ask for children from the goddess believed to live in the tree. The silk and cotton saris and shawls are placed on the tree to express gratitude after their wishes have been fulfilled and the women have conceived or delivered a child.

One of those huge banyan trees close to a village near Kumbakonam was the scene of the following event:

After asking permission to investigate the history of the tree and graveyard, the *pūjārī* gave her consent and blessings, lightened the *āratī* (sacred fire), and distributed the ash on the forehead of the researcher and his assistant. The tree was said to be approximately two hundred years old. In the middle of the nineteenth century, the twin sisters Krishnamal and Duraiamal died of smallpox when they were only six years old. The incident was tragic, and the whole village took part in the funerals when the dead bodies were buried under the protecting shade of the banyan tree. The presence of the dead girls' spirits was felt so strong that it attracted many devotees to come and pray under the tree. Women who were not able to have children prayed for offspring. Many of those wishes became fulfilled and the devotees came back to offer saris and other valuable garments to express

their gratitude. As a result, the place has become a temple that is visited by many people from the surrounding villages, with weekly *pūjās* held on Tuesdays and Fridays.

During this investigation, while we were talking with the local people about the temple, the *pūjārī* suddenly started shouting, almost screaming, while moving her body in a kind of dance.

> *"...don't talk about me, leave me in peace, don't talk about me".*

These were the words she repeated as she fell into a kind of trance from where she finally tumbled on the stony ground, losing consciousness. The younger boys that followed the interview and watched the scene created by the *pūjārī* ran to the river to bring water to sprinkle it on her face. After a short while, the woman opened her eyes again, and the youngsters lifted her up from the ground. Being conscious again, the *pūjārī* behaved as if nothing had happened.

The interviewees had the impression that the woman was contacted by the spirits of the twin sisters to bring the message that they felt disturbed by the noise and presence of the unusual crowd under the tree. We were advised to leave the place after walking around the tree clockwise, the way worshippers are supposed to do.

Interviewees indicated reported about various incidents that they witnessed when deities contacted people, mostly women, to bring forward their message. As in the above described case, the contact usually takes place after the recipient enters a trance stage, which lasts for a short while during which the person seems to be unaware of what happenes to her/him. A similar case involving the encounter of a tree deity and a person was reported by a *pūjārī* in a sacred grove near Tiruvanumalai. He told that in one of the *pūjās* that was performed for the goddess *Amman,* a dispute began between a father and his son during the ceremony. At one point, the nine year old son started shouting to his father and slapped him on his face:

> *"...I told you not to come here to my temple. Go away immediately".*

The interviewee (*pūjārī*) said that the father ran away, out of the forest. The *pūjārī* calmed down the boy, who was in a strong emotional state, and asked him what had happened. The goddess *Amman* was still talking through the boy, saying:

> *"...he should not have come here. He knew it".*

The explanation of the priest was that there seemed to have been actions performed by the father that were against the *dharmic* law and he should not approach any sacred place before going through the rituals of purification. Probably the father became aware of the powerful attack of the deity through his son, which made him run away.

Still a third incident was reported by an interviewee, the caretaker of a temple, where *Muneeswaran*, the feared male god, had his residence in a bodhi tree. During one of the annual great festivals for *Muneeswaram*, a devotee who had left the village years ago, and was now taking part in the celebration, was contacted by the deity. At some stage he started attacking the participants with words that were believed to have been transferred to him by *Muneeswaran*:

> *"...you people have promised me to sacrifice two goats, but you didn't keep your words. You are now given a last chance to stick to your promise otherwise you will come to experience my anger".*

The interviewee said that there was no way that the person who uttered these words could have known of the promise the temple committee had made some time ago to sacrifice goats. During the same week a festival was quickly organised where 16 goats were sacrificed and offered, together with boiled rice, to appease the angry god.

Those were the incidences where the deities residing in the trees contacted and spoke through the devotees. The stories told above were witnessed by the interviewees themselves. According to their judgement, the persons that are contacted by the deities are described as pure souls, devotees living according to righteous *dharma*. Whatever the message brought forward, whatever demands it consists of, it will be definitely fulfilled very soon. The fear of the villagers to upset the deity is real and everything will be done to keep a good relation with her/him.

5.6.5. *Prosopis juliflora* as a sacred tree

Near Baruva, an approximately 40-year-old prosopis tree had been chosen as a tree of worship. The people living in the street next to the tree, all belonging to the Backward Caste (BC), celebrate *pūjā* beneath the tree every Tuesday evening. The tree is situated in the middle of the village beside one of the bore wells where people come to fetch drinking water or have their bath. The name of the female goddess is *Bandaru Potanna,* and she is worshipped as the protector of the village. During the *pūjā*, the devotees offer her their prayers and light the sacred fire.

An 84-year-old, man who took his bath at the well every evening, told us that, before, in the place of the prosopis tree, a huge neem tree had been the abode of the village deity. The tree had become old and turned out to be dangerous for the small houses surrounding it, which brought the villagers to the decision to cut it down. Later, in its place, a prosopis tree started growing naturally and after reaching a mature height, the villagers continued to worship the tree, recognising it as the new residence of the protecting village goddess. At some point, the family who has their house right behind the tree wanted to fell it because it did not allow enough daylight into their home. This was rejected by the villagers with the argument that this act would cause danger and accidents to the people of the village.

Outside a village close to Baruva, an old and huge prosopis tree showed the same marks of *pūjā,* like red powder at the bottom of the tree and the burn marks from incense sticks. An old woman, who estimated her age at around seventy years, was answering questions while sitting in her hut that was built under the tree. She explained that this tree was worshipped as the residence of the female goddess *Centamony*. Laxmana, the *pūjāri*, told us how it happened that this prosopis tree had become a place of pilgrimage:

> *"…already as a young girl, I had very religious feelings and it sometimes happened that I fell into a kind of trance while performing the rituals during the pūjā. One day, one of those trance-like conditions became very intense and at the peak of it, I suddenly got the sight of the goddess who introduced herself as* Centamony. *She ordered me to go out of the village to find the place that she had chosen and which she would appoint to me and where the villagers should build a temple. The goddess will reside in a tree and protect the village from evil. Only some days after this incident, I have been out of the village on my way home when I suddenly got a strong feeling and intuition that this was exactly the tree chosen by* Centamony.*"*

With the help of the villagers, she built a small hut under the tree, using prosopis stems and a roof made of crop residues (Figure 22). After completing the shelter, the villagers began to build a temple made of stone to worship their new goddess. At the time when this interview was made, the temple was in the final stages of completion.

During the time the researchers were listening to Laxmana's story about the tree and its history, people were passing the place, stopping for a while in front of the tree and reciting short prayers, before continuing their way. The weekly *pūjā* was held on Tuesday evenings when a big crowd of villagers came to take part in the ritual ceremony. Tuesday and Friday are regarded as auspicious days for *pūjās*.

In the south of Coastal Andhra Pradesh, outside the town of Tirupathi, another prosopis tree bore the signs of a temple tree. A *śivaliṅgam* made of stone in the middle, surrounded by small stone figures and decorated with fresh flowers, were the visible signs that the tree was worshipped as the abode of a deity. A village woman, working in the field close by, came to tell about the significance of the village temple. She said that the protecting deity that lived in the tree was *Nāgalamma.* Every Friday evening, the villagers gathered under the tree to perform a *pūjā* in honour of their deity. She was known to have helped many women to become pregnant after years of infertility.

Figure 22. A sacred *Prosopis* tree.
The building of a stone temple had begun after the tree had been recognized as the residence of the deity Centamony.
(Photo: Kurt Walter).

5.7. The Pongal festival

The Pongal festival is a celebration in South India that is of utmost importance. Farmers start the new agricultural cycle by thanking the gods for the previous harvest and asking for a fruitful farming season with plenty of rice, grain and fruits. Although the festival is not directly related to trees in general, or prosopis in particular, both Pongal and trees are associated with fertility. Furthermore, the Pongal celebration shows the importance of rituals in rural people's everyday life. Similar to the rites connected to trees, in the Pongal celebration the relation between the power and willingness of the gods and the prosperity of the villagers are strongly connected with each other.

Pongal is the "Thanksgiving" of India, celebrated in every village in Tamil Nadu. It is also the name of the main dishes eaten during the festival, consisting of rice and lentils. The Tamil word Pongal means "overflowing" and, thus, the word is translated as "something that is abundant" or simply "boiling over". The dates of the festival are determined by the solar calendar and in 2009 the celebrations took place between the 13th and 16th of January. In a group interview at the entrance of the village of Utkottai, all the important aspects of the Pongal festival were discussed. Each of the four days has a specific significance, and there is hardly anybody in the villages who does not participate in the celebrations. The entire Pongal is a festival, especially, for the people in villages, while in towns usually only the second day of the festival is celebrated.

The first day is called Bhogi. On Bhogi, people clean their homes and old goods like furniture, cloth or anything that is unwanted will be collected and burned during the evening. It is a kind of common spring cleaning day where many villagers even whitewash their houses, while the streets are cleaned with a mixture of cow dung and water.

The second day carries the name Surya Pongal, or Thai Pongal, and it is the start of the main festivities. It is the day when the sun is worshipped (*sūrya* in Sanskrit for sun). Women wake up early this morning and paint beautiful *kolams* with coloured rice flower in front of the entrance of the houses. Sugarcane, bananas, ginger and turmeric are placed on open spaces to be offered to the sun as they dry in the hot atmosphere. People wear their new dresses, invite family friends, and start cooking the important Pongal meal with their new cooking utensils. Rice from the new harvest is cooked in pots with milk until it overflows with foam. The overflow of rice invites children and adults to shout joyfully "Pongal o Pongal", words with no real meaning, just expressing their happiness. The elders, then, bless all the family members.

Mattu Pongal is the name of the third day of the celebrations. The Tamil word Maatu means cow, bull, or cattle. India is known as the land of holy cows, and cattle represent prosperity and wealth. On this particular day, the cows and bulls are washed, painted with holy symbols and decorated with garlands. They will also wear their new equipment, like nose rings, bells, and reins. The main attraction of the Mattu Pongal day is the bullfight, called Jalikattu, where young men show their strength trying to wrestle the bulls to the ground. The bulls are chased to run through the streets while huge crowds shout "Pongal, Pongal", to encourage the young men in their fighting game that resembles the bullfights in Europe. However, the intent is not to hurt the bulls although the young fighters and the witnessing crowds might become injured.

The fourth and final day of the festival carries the name Kaanum Pongal. The villagers stressed the fact that this day is dedicated to women and family affairs. On this day, the prayers are directed towards the unmarried women (the Tamil word kanni means unmarried) so that they might find a good husband. The women pray for a long life and the prosperity of their parents. On this day,

parents or brothers invite their daughters or sisters to celebrate together with their families. Thus, the festival ends with the reinforcement of traditional family values.

Similar to the celebrations in honour of the tree deities, also the Pongal festival aims at persuading the uncontrolable forces in nature. A successful crop cycle is crucial for the livelihood of the rural people. The celebration is at the same time a thanksgiving for the year that has passed and the expression of hope for a fruitful and prosperous agricultural season to come. It brings the family together because, traditionally, all the members travel home to their village, even from far distances. In these rituals, the first priority of the community is to please the gods that are believed to determine the livelihood and welfare of the society. While the rites related to trees usually are connected to one particular deity, the Pongal festival includes all the village deities at the same time. Thus, trees and crops, forests and crop-fields, livestock, people and deities are all united in this most important celebration of rural Tamil Nadu.

6. Discussion

6.1. Presentation of the discussion

The first part of the discussion provides a synthesis of the livelihood situation in Andhra Pradesh. It illustrates the social structure of the rural people and their ways of acquiring the means for their livelihood. The discussion continues with describing the relations and attitudes of the various groups of people towards prosopis. It summarises the various uses of prosopis and the potential of this resource to benefit people and the environment. The discussion also highlights the risks that are involved in a further uncontrolled invasion of prosopis, as perceived by the people in the research area as well as experienced in other parts of the world.

Another, separate part of the discussion, deals with the cultural and religious classification of trees in India and the relation to the alien prosopis. This specific section relates to the prevailing habits of tree worship and environmental protection.

Finally, the Bishnois and the Chipko Andolan stories are taken as examples of the resistance that arises when cultural and religious values are disregarded. These incidents show the strong devotion and respect of Hindus towards nature in general and trees in particular.

6.2. Livelihood characteristics of rural households in Andhra Pradesh

6.2.1. The people and their livelihood in the research area

The majority of the people in the research area belong to the Backward Castes (54 percent) and the Scheduled Castes (including a minority in the Scheduled Tribes, 32 percent). Both Scheduled Castes and Scheduled Tribes are commonly mentioned together because they constitute the former group of casteless people. They are the most vulnerable people, with the highest rate of illiteracy. A minority of the people in the research area are members of the Forward Castes (14 percent), most of them belonging to the Brahmin Caste, which is traditionally the most privileged caste in India.

The division of professions are in accordance with caste affiliation. While most of the households of the Forward Castes are involved in farming (73 percent), the majority of the lower caste households from Scheduled Castes and Scheduled Tribes (43 percent) make their living as labourers, with only 26 percent being farmers. In between are the households of the Backward Castes, which usually practice traditional professions, for example as blacksmiths, carpenters, or fishermen. In the past, when the population was smaller and resources and jobs were available, certain professions were only occupied by the group of people affiliated with the particular caste. However, the pressure of population growth does not allow such privileges anymore. Thus the fishermen of the coastal areas complained that nowadays people do not respect the coherence of caste and profession and people from all castes are fighting for diminishing resources, in their case for fishing in their traditional territory.

Among the farmers, the distribution of land is such that 56 percent of the Forward Castes own and cultivate holdings larger than 5 acres, while the occurence of similar size plots among households of the Scheduled Castes and Scheduled Tribes are only 7 percent. The avarage plot sizes among these households (which make up 62 percent of the total population in the research area) are smaller than

two acres, and this land is mostly contributed by the government, according to the size of the household. The harvest of the usually rainfed fields normally consists of rice and a few other subsistence crops. While farming provides at least subsistence income, landless people are totally dependent on the jobs available during the agricultural season. The majority of landless households belong to the lower castes (Scheduled Castes, Scheduled Tribes with 38 percent and Backward Castes with 37 percent).

As the research reveals, the former casteless households from the Scheduled Castes and Scheduled Tribes are the most underprivileged groups in the research areas. The situation is similar among the Backward Castes who no longer enjoy the privilege to exclusively practice their affiliated profession as it was in earlier years when traditionally certain professions were only practiced by the corresponding caste. Both castes possess the smallest landholdings and form the largest group of people that does not own any land at all. It can be concluded that the lower the caste, the more vulnerable are the people and the lower their means to secure a livelihood.

Household income patterns

The income of most of the households was in one or another way connected to agriculture. While rainfed agriculture on smaller plots provided subsistence income, farmers who cultivated larger fields and, particularly, those who were able to practice irrigated agriculture, were able to make agriculture a profitable undertaking. Despite the income from cash crops, many of the better-off farmers had diversified their income by planting trees on farmland or by further processing their crops, like the drying of tobacco leaves after the harvest. Those farmers were the employers of agricultural labour during the cropping season.

Depending on the monsoon (and the rains had reportedly been scarce during the time preceeding this investigation), the subsistence farmers could fulfill most of the immediate needs but they were left without the important cash income necessary for improving their livelihood. Although farming was managed by engaging the whole family in agricultural work, they had to earn additional money by offering their labour to commercial farmers. Usually the women and children could find employment by weeding the cash crop fields of irrigation scheme farmers. The landless households were entirely dependent on employment, which was basically possible only during the cropping season.
The results showed that, ultimately, all households were in one or another way engaged in using prosopis as a source to improve their livelihoods. While, for some farmers, the exploitation of prosopis meant an additional income, for others, like the landless low-caste people, it was the essential resource that saved them from starvation.

There were multiple possibilities for people to benefit from prosopis. Landowners rented the prosopis trees on their land to people who cut them and sold the wood further to biofuel power plants, firewood entrepreneurs, brick factories, charcoal producers, or other enterprises using prosopis fuelwood. Others employed people on a day-labour basis to cut wood and sold the wood themselves. Farmers who cultivated tobacco, for instance, would use their own prosopis resources for drying the leaves. For many of the landless people, prosopis provided the only income source, particularly during years of insufficient monsoon rains. They either found themselves employed, cutting and trading the wood, or they did the job on their own, using the free prosopis resource on wastelands.

Prosopis provides a variety of services and income opportunities for people of all castes. However, this research has shown that especially the people from the lower castes and the casteless are the greatest beneficiaries of the resource. Those families who do not own any land for cultivation and are dependent on employment in the agricultural sector can make use of the tree in several ways to diversify their livelihood assets.

People's awareness and perceptions about Prosopis

The results indicated that the people in the research area were very aware of the multiple benefits and problems that prosopis possesses. In general, people, especially women, had an overall positive attitude towards prosopis. This was due to the fact that women of the household are mainly responsible for the collection of firewood. Since huge areas of wasteland occur in the arid zones of South India, women generally do not have to go long distances to fetch firewood, saving them time and energy. Actually, the only negative responses that questioned the usefulness of the tree came from male interviewees. Since they usually fell the trees and bushes, they were the ones who complained about the heavy work involved. Quite often, they also reported injuries caused by the thorns of prosopis. Despite the importance of the tree as a fuelwood source, it was recognized by both men and women that prosopis is beneficial especially for the poor households.

The percentage of female interviewees was rather low compared to the male respondents. The reason lies in the cultural code that does not allow men, especially from outside the larger kingroup, to contact women outside their home or without a relative close by. Thus, it was mainly the responsibility of the assistants to decide when it was appropriate to contact the women. However, the results indicate, that a stronger participation of women in the research would have only strengthened the positive attitude.

The attitudes towards prosopis in other parts of the world where the tree has invaded drylands similar to those in South India have often been very negative. In the Sudan, where prosopis had invaded the agricultural scheme of New Halfa, the perception of prosopis has been overhelming negative (Walter 2004). There too, many landless people have benefited from clearing invaded prosopis fields and selling the wood as fuel, or processing and selling it as charcoal. Similarly to South India, people living in the areas around New Halfa faced a substantial need for firewood. In the eastern state of Kassala in the Sudan, 69 percent of the interviewed people called for immediate eradication of prosopis from the area (Magid 2007).

The prosopis invasion of the land around Lake Baringo in Kenya raised even more resistance against the invader. There, 85 to 90 percent of the people living in the affected area demanded the immediate eradication of the tree (Choge *et al.* 2002; Mwangi and Swallow 2008). In the irrigated agricultural scheme in Bura, Kenya, the opinion about prosopis was positive among the pastoralists who were utilizing prosopis pods as fodder for their livestock. Also, tenant farmers appreciated prosopis because they found it useful to plant the trees as hedges around the field and their houses. On the other hand, farmers complained about the invasions of prosopis into their crop fields and along the irrigation canals. They were even reluctant to use the tree for fuel because they were afraid to get injured by the thorns (Johansson 1995).

The negative perception of prosopis in the Sudan was influenced by the state officials, whose opinions spread to the local authorities who were in contact with local farmers through the extension services. In 1995, the Government of the Sudan proclaimed an official "ban on prosopis", which prohibited any further planting of the tree in the country. The Sudaneese government

declared 1995 the year of prosopis eradication, allocated funds to this end, and mobilised people to participate in the campaign (ElSiddig *et al.* 1998). Thus, prosopis was banned officially and there was no discussion on using the tree even in areas where it had proved to be very useful, for instance, in shelterbelts against sand dune invasions in the very dry regions (Laxén 2007).

It is possible that the reasons behind the rather positive attitude towards prosopis in the present research area might be related to the relatively recent appearance and invasion of prosopis (according to many observers, only in the last few decades). For instance, the invasive expansion of prosopis in the Sudan started already in the 1960s and 1970s (Laxén 2007). Also, the intensity of the invasion in South India has not yet reached the extreme proportions found in the New Halfa Agricultural Scheme in 2003 (cf. Walter 2004). Resistance to prosopis has been found in parts of India, like in Rajasthan (Binggeli 2001; Gold and Gujar 2002) or in the western state of Gujarat (Tewari *et al.* 1998).

Another explanation behind a more positive attitude of people to prosopis may be the influence and capability of the authorities to influence people's opinions. In the present study area in South India, the Forestry Departments and Extension Services encourage people to make use of prosopis in whatever way possible, particularly to use it as fuelwood. As a result, there was a lower risk that people would encroach into protected and restricted forest areas to collect fuelwood.

6.2.2. The fuelwood resource

The results indicated that fuelwood is one of the very essential resources sustaining livelihoods in the arid and semi-arid areas of South India. There is a substantial need for fuelwood that also is related to the Indian food culture. The main dishes in Indian cuisine consist of rice and *dahl* (lentils), which both need considerable cooking times and thus, a high energy input in the form of firewood, charcoal, or liquid gas. Further, it is a cultural habit to prepare the meals fresh, which also has its reason in the lack of refrigerators to store food for the next day.

The present investigation showed that the choice of fuel source was strongly associated with the caste of the household. The interviews revealed that people belonging to the lower castes were the ones most dependent on prosopis as a fuelwood resource. Although there was a trend in the research area to use fuel sources other than fuelwood, like gas, especially in towns and urban areas, for most of the underprivileged households, prosopis remained the essential and most often the only source of household fuel. A tree that grows on wasteland and belongs to the government is free to use for anybody, without any restrictions. Thus, it is mainly the physical input of people that is needed to obtain the important fuelwood. In the dry regions of the research area, there were plenty of prosopis trees available on wastelands. However, there are also wastelands that belong to the village *panchyat*, mostly at locations close to biopower stations or other large consumers of woodfuel energy, and trees on such land are auctioned to whoever can pay the highest rent.

Although people were aware of the advantage that prosopis gives as a fuelwood resource, they often complained about the unpleasant thorns that cause injuries when handling the tree. Many interviewees mentioned that they would rather use a thornless tree. As described in Chapter 2, there are possibilities to genetically improve prosopis through selective breeding and hybridisation with other less thorny *Prosopis* species, in order to obtain a variety that would make the handling of the tree easier (Wojusik *et al.* 1993; Tewari *et al.* 2000; Ewens and Felker 2003).

Already in the 1980s, the Indian government spent 35 billion Rs in various afforestation projects to cover the increasing demand for fuelwood in India. It planted 13 million hectares with *Eucalyptus* and *Casuarina* species. The projects aimed at reducing the risk of encroachment into protected forest areas by people in search of fuelwood. However, because of mixed results, the government soon lost interest in supporting new afforestation plans (Köhlin and Parks 2001).

The older people among the interviewees remembered that a few decades back, prosopis was still not available in such dense formations as today. Instead, there were indigenous trees that filled the gap of fuelwood supply during those days. However, the trees were not used in a sustainable manner, cutting only branches and twigs for fuel, but were felled and sold to the growing urban centres instead of supporting rural livelihood. The city of Bangalore alone got 95 percent of its annual wood requirements from private contractors who purchased firewood from landowners in the nearby villages and from government auctions. Thus the villages lost a valuable source of tree biomass (Ravindranath *et al.* 1991). With the increased wood supply now resulting from the prosopis invasion, the support of people's fuelwood needs can again be satisfied.

There is also an increasingly high demand for charcoal in urban centres that is mainly consumed in restaurants, small-scale iron workshops, and numerous other small enterprises. The production of charcoal usually happens at a considerable distance from the place of consumption. Transportation of wood is relatively expensive, thus, its conversion into charcoal is very convenient since it upgrades the product to higher energy content and better economic value. There were plenty of charcoal manufacturers in the present research area, and there is capacity for many more. Charcoal production is usually situated close to areas of high prosopis occurrence and it plays a considerable role in the rural economy. In South India, charcoal production could be optimized through the introduction and use of "retort kilns", which are already popular in many other places outside India. Those kilns produce charcoal in a shorter period of time (8-48 hours) with approximately 32 percent conversion efficiency (Tewari *et al.* 2000).

6.2.3. Options for eradicating and controling *Prosopis*

Despite the recognised benefits of prosopis for the people and livestock in the research area, negative effects caused by the prosopis invasions have called for eradication of the tree. Ecologists and the National Forest Department in Hyderabad[13] have become alarmed by the uncontrolled prosopis invasion into irrigation canals, grasslands, croplands and protected forests. The exotic species has escaped from the range of its introduction, continuing to invade new areas at the expense of native species. According to the National Forest Department, there are frequent complaints from farmers who are affected by prosopis invading their fields from nearby fallow lands. Invasions have mobilized agriculturalists and landowners, who have asked the Forest Department in Rajasthan, Haryana, Gujarat and Tamil Nadu to stop any further planting of prosopis. In an article in "The Times of India" (2005), scientists at the Centre for Environmental Management of Degraded Ecosystems (CEMDE) at Delhi University claim that prosopis is responsible for a continued decrease in the ground water table and a drying up of the soil surface that kills the vegetation in the green lands of Delhi. The Vice Chancellor demanded an immediate eradication of prosopis from the area. According to an expert group of the CEMDE, prosopis should be replaced by indigenous plants after the eradication.

[13] Personal communication with Dr. T. Pullaiah at the University of Anantapurm and Dr. Ramana Murthy at the National Forest Department of Andhra Pradesh in Hyderabad.

The option of complete eradication is important to consider in limited areas where prosopis causes economic losses to farmers or endangers ecologically important habitats. In South India, bushy thickets of prosopis frequently occur on government lands that are left fallow. It would need the planning and financial support of the state authorities to initiate eradication campaigns. The use of heavy equipment to uproot the whole plant is further restricted on sites of Common Property Resources (CPR), like catchment areas of village water reservoirs that are designed for village deities. Those sites are important socio-religious grounds, and people would not allow any destruction that would be caused by bulldozers (Kathiresan 2006).

In this research, it became apparent that eradication of prosopis even in limited areas was not successful. As shown in the results (Chapter 5.6.), there have been attempts by the village community to eradicate prosopis from an important water pond of the village. However, after only two years, the trees were back around the banks of the pond, and according to some of the villagers, spreading even more aggressively than before. The eradication campaigns on the banks of the irrigation canals in areas of Coastal Andhra Pradesh have shown similar negative results. There, too, it took only a few years until the trees were back again. Other similar invasions of prosopis in the near proximity of reservoirs for irrigation and village ponds have been observed in several dry areas of South India (Kathiresan 2006).

Comparable experiences of unsuccessful eradications were obtained in Bura, eastern Kenya, where the first attempts of simple cutting did not show any desired results because the stumps coppiced vigorously in places close to water sources. Only uprooting and burning the stumps guaranteed success in eradicating prosopis where it had already been naturalised (Maua *et al.* 1991). In other reported eradication campaigns, the additional use of herbicides to hinder resprouting was observed to bring more satisfactory results (Csurhes 1996; Babiker 2006). However, the use of such chemicals close to water sources that are used by people is not acceptable.

The implementation of eradication campaigns should not stop at the stage where the trees are removed from the ground, using whatever above-described methods. There needs to be a well designed plan for the future treatment of the newly cleared land in order to hinder the regenreration of prosopis from the latent seed bank. One possible option is to plant indigenous species on the newly cleaned land. The shade that is cast by the new seedlings would give them an advantage and hinder the growth of new prosopis seedlings. It has been observed in the Sudan that intensive use of prosopis has triggered a natural regeneration of indigenous species which gradually out-compete, the invasive prosopis (Laxén 2007). It is also very important to restrict animal movement in areas that are cleaned from prosopis, since the droppings of animals that graze on prosopis pods are one of the main agents of its dispersal (Harding 1987).

The results showed that the farmers in intensive cropping regimes use prosopis as a natural fence around their fields. However, none of the interviewed farmers who owned such fields was worried that there would be a risk that the prosopis fencing might invade their cropland. The farmers assured us that it is a common practise to immediately pull out even the smallest prosopis seedling when it appears on the field. This is probably the most effective method of controlling prosopis invasions into crop fields, in the research area and elsewhere. The problem, however, exists where land is not owned privately and used to its greatest potential. According to the interviewed farmers in the hot and dry areas of southern Andhra Pradesh, there is a high risk that if the prolonged periods of drought continue, the invasion of prosopis into their rainfed agricultural fields cannot be avoided.

However, during the field investigation, personal observations while travelling through the rural dry areas of Andhra Pradesh and Tamil Nadu, conveyed the image that the more prosopis infestations there were around a rural village, the poorer were the people and the infrastructure of the places. High invasions appear on lands that are not cultivated and most of the agriculture in those dry areas depends on rain because of the lack of natural water sources or irrigation schemes. Especially for those areas, it would be vital to get the prosopis invasions under control and create new markets based on this tree so that people can have optimal benefits from this natural resource. As already pointed out, a complete eradication is rather unrealistic. It is also not desired because it would leave the people without an important fuelwood resource.

The annual rainfall in Tamil Nadu and Andhra Pradesh is divided into two rainy periods: the south-west monsoon, that supplies 66 percent, and the north-east monsoon with 24 percent of the annual rain. An additional 10 percent rainfall is received during the summer and winter months outside the monsoon period. As shown in table 26, almost the entire decade prior to the fieldwork in 2005 was characterized by insufficient monsoon rains. Official statistics confirm the observations of the people. In 2004, there was 28 percent less rain than in normal seasons. Consequently, large parts of crop fields in particular drought affected regions remained uncultivated. This created niche opportunities for prosopis to occupy the fallow land. At the time of this research in 2005, the monsoon had started with plenty of rain, which mobilized the farmers to start immediate prosopis eradication activities on their fields. Statistics on monsoon rains indicate that the following years were supported by sufficient monsoon rains with the exception of 2009 when there was a deviation of 27 percent less rain then normal (Table 27).

As the interviews have revealed, the preceding decade was characterized by increasing heat along with the drought periods. Especially the year 2005, was extremely hot, with temperatures climbing up to 50° C and some days even above.

Table 26: Rainfall periods during south-west and north-east monsoon periods in Andhra Pradesh from 1995-2005 (modified from Meterological Department of Hyderabad 2005).

Year	South-west Monsoon (June to September)			North-east Monsoon (October to December)			Total (June to December)		
	Actual	Normal	% Dev.	Actual	Normal	% Dev.	Actual	Normal	% Dev.
1995-1996	627	634	-1	299	206	45	926	840	**10**
1996-1997	737	634	16	279	206	36	1016	840	**21**
1997-1998	520	634	-18	233	206	13	753	840	**-10**
1998-1999	755	634	19	300	206	46	1055	840	**26**
1999-2000	535	634	-16	135	206	-34	669	840	**-20**
2000-2001	759	624	22	92	224	-59	851	848	**0**
2001-2002	534	624	-15	264	224	18	798	848	**-6**
2002-2003	417	624	-33	156	224	-31	573	848	**-32**
2003-2004	598	624	-4	218	224	-3	816	848	**-4**
2004-2005	481	624	-23	133	224	-41	614	848	**-28**

Table 27: Rainfall periods during south-west monsoon periods in Andhra Pradesh from 2005-2010 (modified from Government of Andhra Pradesh 2010).

Year	South-west Monsoon (June to September)		
	Actual	Normal	% Dev.
2005	690	624	**10**
2006	627	624	**0**
2007	747	624	**20**
2008	642	624	**3**
2009	454	624	**-27**
2010	808	624	**30**

In Kenya, the final lessons learned from the Bura experience were that it is practically impossible to successfully eradicate prosopis completely. In order to keep agricultural fields free of infestations of the tree, strict control and immediate action to pull out even small seedlings before they become established is needed (Otsamo 1993). Eradication is in any case highly labour intensive and can be only considered in small areas and where cheap labour is available. In North and Central America there have been attempts to eradicate *Prosopis* spp. for half a century using several of the above described methods. However, it has proved to be very expensive and basically unsuccessful over a longer period of time (Pasiecznik *et al.* 2001).

The eradication campaigns of the sugar factory in the New Halfa Agricultural Scheme in Sudan, and the following eradication of a wider area surrounding the sugar cane plantations a few years later, have shown that relatively small areas of prosopis invasions can be successfully cleared. The New Halfa Agricultural Scheme in Sudan started its own intensive eradication programme in 2004 and, according to recent information, the project was completed successfully in 2007 with the financial support of IFAD (personal communication).[14]

Before the start of the campaign in 2004, the manager of the scheme and leader of the operation had already planned the aftermath of the eradication according to the model of a similar eradication in a smaller limited area of a sugar factory within the scheme[15]. According to the sugar factory experience, the keys to a successful eradication campaign are control of the movement of animals and strict observations of the fields to keep them absolutely clean from the smallest seedlings. In the larger area of the southern part of the scheme with intense prosopis invasions, no tenant farmer was allowed a plot without assurance for care against new infestations. Monetary punishments were planned for farmers neglecting this common task.

Similar to New Halfa, in the Zeidab Irrigation Scheme, also in Sudan, eradication of prosopis has started, using both mechanical and manual methods for uprooting the tree. However, the high cost and poor follow-up procedures have caused significant re-infestation of prosopis in the area (Babiker 2006).

[14] Phone call to the secretary of the New Halfa Agricultural Scheme, Sudan, in 2009.
[15] Personal communication with Mr. A. Osman, the manager of the New Halfa Agricultural Scheme.

As an alternative to eradication using mechanical and chemical methods, there are ongoing trials that test methods of biological control for alien invasive plants. In the case of prosopis, for instance, the leaf tier *Evippe* sp. #1 has been suggested as an agent for getting the prosopis invasions under control (van Klinken 2003). However, further studies are needed to find out more details about the host specificity of certain insects to avoid an undesirable attack on other trees which might lead to new ecological imbalances. In the case of *Evippe* sp. #1, trials in quarantine were conducted to predict and determine their host-specificity. The results strongly suggested that this insect would only attack *Prosopis.* It was concluded that the chemical orientation, physical stimulation, and complete development of *Evippe* sp. #1 are restricted and specific to *Prosopis* species, which later lead to the release of the insect in several areas in Australia (van Klinken 2000).

Due to the many useful attributes of *Prosopis* species, biological control that does not destroy the tree itself but focuses on the destruction of the seeds through seed-attacking insects is considered a vital component in the control of prosopis invasions. As mentioned, prosopis has long-living seed banks which might make the procedure a long-term effort. In its native range, seed feeding beetles of the family Bruchidae destroy a large amount of *Prosopis* seeds, thus limiting the possibility of invasion (Pasiecznik *et al.* 2001). In South Africa, the seed-feeding bruchids of the species *Algarobius prosopis* (J.L. Le Conte) and *Algarobius bottimeri* (Kingsolver) were released for the biological control of *Prosopis* spp. Both species have established well and within only 27 months after release, it was evident that *A. prosopis* had destroyed 92 percent of the seeds of 10 month-old pods (Zimmermann 1991).

Biological control will not be sufficient as a single measure to reduce or stop further invasions of *Prosopis* spp. Even in their natural range, where many different insects regularly attack the trees, *Prosopis* spp. have shown adaption and resistance to those infestations and are still able to become invasive (Pasiecznik *et al.* 2001). The success of bruchid beetles in introduced areas of exotic *Prosopis* species is promising but it still needs more research before introduction on a large scale is viable. In areas where invasions of *Prosopis* species cause significant damage to the ecosystem and where farmers suffer economic losses because of crop field invasions, biological control can be used in combination with other eradication methods. However, shifting plants and animals from native to exotic environments contains risks, which need to be assessed and tested carefully.

Climate change might intensify the invasion of alien species because of better adaptation through adjusting their phenology in a more sufficient manner than native species. The results of a study by Willis *et al.* (2010), point towards a strong positive correlation between climate change and the naturalization and invasion of alien plants. Phenological research indicates that particularly invasive alien species have significantly increased in abundance, relative to the natural flora, due to an increase in temperature since 1900. Adaptive changes in flowering time according to changes in climate are positively correlated to the fitness of a plant. In other words, plant species that possess the capability of fast physiological adaptation increase their competitive ability in relation to other surrounding plants. Thus, a plant that adjusts its growing cycle so that it starts growing earlier in warmer years, will have competitive advantage in nutrient acquisition and the availability of light. In addition to climate change, also disturbances caused by human activity (such as overgrazing or nutrient enrichment) increases the competitive advantage of exotic compared with native species (Willis *et al.* 2010).

Introductions of *Prosopis* species have been accompanied with poor identification that has let to incorrect classifications. *Prosopis* species are commonly incompatible and need to cross with another tree to produce fruits. This strategy enables the plant to increase its genetic variability and thus it is able to adapt to various different sites. Frequent hybridisation makes proper identification

of the species a difficult undertaking, which is already complicated due to the close similarity of many of the species with its innumerable varieties and subspecies (Pasiecznik *et al.* 2004).

As a consequence, unclear identification causes difficulties in planning eradication or other means of control programmes, genetic improvements, selection of management practices, or utilization of the *Prosopis* trees. The ordinary *Prosopis* introduced for instance in Brazil, Cap Verde, Senegal, Kenya, Mauretania, and in parts of India, was believed to be *P. juliflora*. As it has been revealed, only in recent years, the species is now identified as *P. pallida*, which has certain consequences to be considered. *Prosopis pallida* is far less invasive than *P. juliflora* and one of the most appreciated species in the *Prosopis* family, having sweeter pods, fewer thorns and a more erect form (Pasiecznik *et al.* 2006a). In case of intended biological control, it needs to be made sure that the bio-control agent must be specific to *P. juliflora* and not to attack trees of *P. pallida.*

6.2.4. Utilization of *Prosopis*

Several ways that people use prosopis and profit from it have already been outlined in the results chapter. However, this alien invader has potential that still remains unexploited in South India. The possibility of using natural manure instead of expensive chemical fertilizer is related to the opportunity to use prosopis as fuelwood. Because of the availability of prosopis, the small farmers in the research area were able to use cattle dung as a natural fertilizer on their crop fields instead of using it as household fuel. It is estimated that each ton of cow dung contains about 8 kg of nitrogen and several other elements that are essential as plant nutritients. Using cow dung as manure improves soil tilth, texture, and fertility (Reddy 1978). There is still the familiar sight of cattle dung cakes drying on the house walls in the hot sun. But the important manure is nowadays increasingly utilized as fertilizer instead of being burned to prepare the daily meals.

One potential of prosopis that is not yet utilized in the study area is the use of the tree to rehabilitate degraded soils. There are different grades of degradation of lands that have been left fallow in South India and this variation should be considered in land-use planning. While heavily degraded lands can very well continue to provide fuelwood, others, less heavily degraded, carry the potential to be rehabilitated or restored. The capability of prosopis to restore those lands (as described in Chapter 2) should be used to convert wastelands for cultivation (Singh *et al.* 2000; Bhojvaid and Timmer 1998; Lal 2006). In addition, the ability of prosopis to remove or render harmless environmental contaminants in many areas of South India would provide more cultivable lands (Senthilkumar 2005; Prasad 2007). Although the process of restoration or rehabilitation takes several years, the possibility of increasing the area of arable land with almost no monetary input is very promising (since prosopis is already growing on those lands or it can be easily planted). The final conversion of the invaded land into agricultural fields will require a heavy use of labour and equipment to cut the trees and plough the fields. This would need coordination and financial support from forest authorities or other national organisations. It also would create new employment possibilities in those areas.

The present study shows that herders let their sheep and goats browse on prosopis pods. However, there was no reported case in the research area where the pods were collected to be used as livestock feed in times of scarcity. On the other hand, livestock holders spent relatively much money, in some cases even half of their income (see Box 2), for purchasing animal feed. Here lies an unused potential that could be exploited by livestock owners. Pods could be collected, processed and added to other ingredients to produce a protein-rich and cheaper variation of animal feed that

could replace available market products (Rawat *et al.* 1992; Ravikala *et al.* 1995). This would not only save money but also create additional working possibilities in regions where there is a great lack of employment. In addition to the above benefits, there is the important aspect of controlling further invasions of prosopis. After crushing and milling the pods, seeds are not capable of germination and the process would, thus, eliminate the spreading of the tree through animals (Felker 2003).

Prosopis pods are also used to supplement the human diet (Felker 2004). Although the pods of *P. cineraria* are used for cooking in India (Tewari 1998), pods of *P. juliflora* are claimed to be too bitter for human consumption and are not used as human food in any part of India. However, in South American countries, where prosopis is indigenous, pod flour is used to prepare biscuits. In Peru and Brazil, pods of prosopis are used to prepare coffee substitutes and syrup (Tewari *et al.* 2000). Beans made from *Prosopis* species have also been important food staples for many American Indians in the south-western United States. Annually they gathered thousands of tons of them and used them especially in years of food shortage. Often they have been the only sources of food available (Rogers 2000). Although the transfer of *Prosopis* species from their native range into new ones has mostly succeeded, the indigenous knowledge of many of their uses has not followed the introduction of the species.

Production of fine timber

The results of this study indicated that there is an increased demand for large-size prosopis timber for manufacturing various products like furniture or boats. Large trees of more than 25 cm diameter are desirable and can be achieved through various stand management practices. There is no need to establish prosopis plantations especially for this purpose. There are already large areas of invaded wastelands that can be managed to produce stem sizes that are needed in the wood manufactoring industry. As outlined in chapter 2.1.5., it is possible through silvicultural management methods, like pruning and thinning, to grow straight and single-stemmed trees to desired sizes (Felker and Patch 1996; Patch *et al.* 1998; ElFadl and Luukkanen 2002).

In areas where prosopis grows abundantly, it would be possible to demarcate suitable stands in order to apply techniques that produce high-quality wood. An optimal stand, which is managed and reduced to 100-125 trees/ha would produce stems with diameters of about 35 cm, which is in line with timber production objectives (Tewari *et al.* 2000). In non-irrigated *Prosopis* stands and plantations in the U.S., a 10-year trial showed an annual diameter increase of 1.5 cm/year, which would produce a stem of 38 cm in diameter in 25 years (Felker and Anderson 1997).

During the last few decades, the attention of forest research and development has been drawn to non-timber forest products (NTFPs), especially to trees outside forests in tropical drylands. Fuelwood, charcoal, pods, honey and other products already mentioned are still essential today to sustain livelihoods in many rural drylands. The monetary value of these products ranks rather low compared to the potential economic benefits that could be achieved through extraction of wood for sawn timber. There is an increasing demand for fine timber and its products in India as well as in other tropical countries. Prosopis stems from 3-22 cm in size are suitable to be used for charcoal, poles, fence posts, carvings or flooring elements. Stem diameters above 22 cm and of a length from 40-100 cm are suitable to be sawn for the manufacture of furniture, flooring, carvings, or boats (Felker 2004).

The quality of prosopis wood is similar to several other species of the genius *Prosopis* and can easily compete with Indian rosewood (*Dalbergia latifolia* Roxb.), Indian teak (*Tectona grandis* L.) and cocobolo (*Dalbergia retusa* Hemsl.), three commonly recognised fine hardwoods, in relation to physical and mechanical properties (Table 28). Tangential and radial shrinkage values are similar in prosopis, which indicate that the wood shrinks or swells equally in both directions. The hard surface of prosopis wood makes it an ideal raw material for furniture. The wood of prosopis is light brown when cut and after drying and aging it darkens, turning into a dark reddish golden brown colour. The colour is considerably darker than in cherry (*Prunus serotina* Ehrh.) and similar in appearance to sissoo (*Dalbergia sissoo* Roxb.). The golden brown colour and a natural high polish give cooking equipment manufactured of prosopis wood an imposing appearance (personal observations). Taking into account all these properties, prosopis can be classified as one of the world's most precious tropical hardwoods (Felker and Anderson 1997).

Table 28: Physical and mechanical properties of *Prosopis glandulosa* compared with three recognised fine Indian hardwoods: Indian rosewood (*Dahlbergia latifolia*), cocobolo (*Dalbergia retusa*), and Indian teak (*Tectona grandis*) (Felker and Anderson 1997).

Property	*P. glandulosa*	*D. latifolia*	*T.grandis*	*D. retusa*
Density (kg/m³)	994–1218	721	850	641
Bending strength (MOE* X 10³	133	97	125	102

Shrinkage (%)	*P. glandulosa*	*D. latifolia*	*T.grandis*	*D. retusa*
Volumetric	8.5	4.7	8.5	7.0
Tangential	4.6	2.2	5.8	5.8
Radial	2.9	2.6	2.7	2.5
Side hardiness (kg)	1234	1059	1437	1453

*MOE: Moduls of elasticity.

In many South American countries, like Argentina and Peru where *Prosopis* species are indigenous, furniture and flooring made of prosopis wood is highly appreciated and the technology to produce sawn timber has been developed during recent years to suit these species (Felker 1998). In India, the potential for managing trees to be used as timber is still under-exploited. However, there are distinctive new methods available. Chainsaw milling is a promising technique that has been developed only recently. It would be a means for increasing timber production from on-farm trees, including prosopis, in the drylands of India and elsewhere. Chainsaw milling has a great advantage because of its high portability, low costs and its capability to produce timber out of fairly small logs that would otherwise only be used for firewood or charcoal production. Chainsaws, including the necessary spare parts, are available in India for US $ 500-1,000. With increasing production, investment in more sophisticated equipment would increase the productivity and profit. It has been concluded that chainsaw milling that is portable and able to cut small diameter, crooked and small

logs is the most suitable method for the conversion of prosopis wood into timber (Pasiecznik *et al.* 2006b).

Small-scale enterprises using chainsaws to mill prosopis would improve livelihoods by adding value to an already existing resource and creating new working places. At the same time, it has a controlling effect on prosopis invasions (control through utilization). A critical aspect of profitable saw timber production is proper marketing. The more the timber fulfills the requirements of the potential user, the more profit can be made. As research has indicated, the most common sizes of timber that are used for the manufacture of furniture and flooring are less than 10 cm in width and 1.5 m in length (Pasiecznik *et al.* 2006b). Those measures can be easily extracted from prosopis trees.

In developed countries, there is an increased awareness about the illegal exploitation of natural forests and consumers want to know the origin of the timber exported from tropical countries. Many enterprises that purchase raw timber or refined timber products demand certification that ensures the end consumer that the wood has been legally obtained and comes from sustainable sources. The demand for prosopis flooring in the U.S. is high and consumers would obviously be ready to pay a higher price when they are assured that they are buying products that increase poor people's livelihood and save forests from being exploited (Felker 2004; Pasiecznik *et al.* 2006b). Certification would add more value to prosopis timber from India and increases the possibility of trading timber products outside the borders of the country.

Why are some of these techniques for managing prosopis not set into practice in the research area? The anwer has to be seen in the light of socio-economic factors and people's perception of prosopis. As the discussions with officials of the Forestry Department revealed, there are no financial resources available to tackle the issue of controlling further invasions of the tree. Until the extent and severity of the invasion problem is recognized on higher official levels, there will be no practical management that can change the course of the present development. Without exception, all the crop fields that faced the problematic of prosopis invasion were owned privately, which would require a united strategy among many small farm holders in the affected areas. This would oblige a united will and even more a substantial financial input of all the farmers involved. Both requirements are today not realized because, as the farmers indicated in the interviews, each one has to work for himself to make some income from farming in times of hardship and there are no resources available to engage in common actions, and even less to support any projects financially.

Although technical solutions for the upgrading of the wood resource, like portable sawmills, are available, they are not feasible because there is no market to sell products such as floorings or furniture. The creation of those markets is made difficult partly because of the low valuation of the wood in people's opinion. There is not enough information to upgrade the quality of prosopis as a fine timber in people's minds. Thus the creation of small scale industries such as sawmills and furniture factories that use prosopis as raw material would also require the extension services to promote information and practical solutions. People would need to be convinced of the quality of the wood and not only perceive it as being just fine for supporting the poorest of the society with fuelwood.

6.3. The role of forests and trees in Hindu culture[16]

6.3.1. The roots of sacred trees in India

The objective of the field research in Tamil Nadu was to get an insight into the Hindu attitude towards nature in general, and trees and forests in particular. In Tamil Nadu, the existence of tree deities, rites of tree marriages and narratives connected to trees and sacred nature is knowledge in the public domain. These subjects were discussed during the interviews and they are also discussed among people outside and within their families. The aim of this thesis was to locate the perception and classification of prosopis, in connection to indigenous trees.

Communities in South India, as well as in many other places around the world, traditionally protect forests or other natural sites that are dedicated to deities or ancestral spirits from exploitation. Those sites are often situated in important watershed areas or otherwise signified by rich biodiversity and a variety of habitats. These sacred sites have been, and are still today traditionally managed by the nearby communities, using methods of community based conservation. Commonly they are not incorporated in governmental conservation activities if they are owned by the communities (Gadgil and Iyer 1991; Bhagwat and Rutte 2006).

During the present investigation, the attitude and respect towards trees and forests was one of the outstanding characteristics of people interviewd. People's attitudes generated the questions about the origin of the attributes that they ascribe to nature. When asking them where they received their basic understanding about the sacredness of nature, they usually replied that the knowledge of sacred nature was transferred over generations within the family from grandparents to parents to their children. The oral transmission of knowledge is part of the traditional education system of Hinduism. Hindu philosophy, moral and ethical values, and cultural codes have been transmitted for generations, both orally and in the written testimony of the Vedas.

The Vedas are the basic historical texts dealing with the role of trees in Hindu religion and they are the background knowledge that formed the opinions of the people interviewed during this investigation. This knowledge about sacred nature has been passed down in Hindu culture through narratives from elders, religious teachings, dancing, singing, theatre performances and observations. These attitudes are still particularly strong in the rural areas of South India, and especially in Tamil Nadu, where the majority of people are Hindus and where there is no history of Muslim invasions that would have interfered with the traditional practices of sacred groves or the overall perception of nature as a sacred union.

The first hymns of the Vedas were composed to praise and glorify nature. Trees were seen as mystic and auspicious. They could be the home of wild animals and snakes. Snakes were feared for their deadly poisons and were always closely associated with trees. Similar to the trees that renew themselves annually by dropping their leaves, so also snakes shed their old skin and emerge anew. Trees were believed to be a domicile for both guardian and evil or demonic spirits. The roots of trees were believed to penetrate deep into the mysterious earth and their branches were thought to reach the limitless sky, unachieved by humans. This made trees mysterious and also suspicious (Nugteren 2005).

[16] Aspects of rituals and tree worship are based on the responses of the village people during the interviews and fortified through references from other authors.

Particular forests are regarded as sacred and are not utilized because of the belief that those specified patches are inhabited by forest deities. However, some species in these forests are carefully used for the preparation of medicines or the repairing of shrines and temples (Hamilton 2002). One of the central themes in the epics of Rāmāyaṇa and Mahābhārata is the exile to the forest. Forests become places of sacredness inhabited by deities, renouncers and sages who are honoured for their extreme surrender to *dharma*. In the texts of the Dharmaśāstra (representing the perspective of the *brāhmaṇic* elite) and the Arthaśāstra, forests are described as places where religious teachers teach their disciples and where older men, who had renounced their family in order to attain liberation, reside as spiritual aspirants. Thus, forests were already long ago associated with wisdom, purity and knowledge. The stories of holy men dwelling in the forests gave, and still give, those places significance and they are frequently visited by pilgrims. Forest and types of wood were differentiated and named according to their specific purposes. Today, *abhayavana* is the term given for protected woodlands. Wood that is extracted for the wellbeing of people is called *śrīvana,* while woodland meant for contemplation is named *tapovana* (Nugteren 2005).

The forest, as a place of fertility and productivity, is symbolized by *Vana Durgā*, the tree Goddess. She is worshipped in different areas with different names. In Bengal, Durgā is associated with different trees like *bodhi* (*Ficus religiosa*), or *sal* (*Shorea robusta*) (Shiva 1989). Tree worship is most significant during *Durgā-pūjā*. Also the banyan tree (*Ficus benghalensis*), one of the most outstanding beauties among trees, is seen as a symbol of the goddess *Durgā* (Sinha 1979).

In the Vedas, trees were classified according to the specific concepts they were connected to. One of them was the verticality of the tree. In the Indian cosmogony, trees and mountains are seen as the supportive power that carries the dome of the sky. Because trees belong to the three worlds, the world below the ground, the human world, and the sky, they were perceived as part of the divine (Bühler 1886). Gods were invoked through prayers and rituals to descend from the heaven down into the trees to give their gifts to the devotee.

Another aspect of the symbolic meaning of trees is the centrality that is connected to the trunk. The visible crown of the tree is connected to the invisible mirrored picture of the root system through the trunk. In villages, huge trees (i.e. fig trees) are the centre of the place under which people meet for social events and for worship. As in Indian mythologies, the idea of a central mountain alternated with the idea of a central tree on top of the mountain, so the village tree was conceived as a social centre, the middle point of the microcosm of the village (Nugteren 2005).

Certain sacred trees are claimed to reach an age of more than 2000 years, like the bodhi tree in Anurādhapura in Sri Lanka. This gives trees a sense of immortality, thus associating them with the ancestors and their spirits. Yama, the god of death in the Vedas, is claimed to collect the souls of the dead in trees (Griffith 1896; Griffith 1895-6). The cyclical renewing of the trees through the juice that flows from the mysterious roots through the trunk to the highest leaves and branches is connected with the life-giving fluids, known as *amṛta,* and so with immortality. For Hindus immortality is not a static eternity but a cyclical continuation of existence (Nugteren 2005).

Fertility is another quality attributed to trees. The ashes of burned forests are known to be good fertilizers for the earth. The so-called "milk trees" are especially associated with fertility. The white sap of the latex-discharging trees is simultaneously seen as the male semen and the female milk. The fruits and blossoms of a tree are seen also as symbols of fertility. For Hindus, the form of the trunk is easily associated with the sexual symbol of the *Śivaliṅgam*. The blossom is connected to the coming fruitfulness while the fruits of the trees symbolize the ripeness and abundance of seeds. Trees are appreciated for their generosity. In the Vedic rituals, wood, milk, butter, and water, are

very important requisites for the various ritual fires and sacrifices. Before the common use of stones, statues and religious symbols of Hindu deities were made of wood (Nugteren 2005).

There are numerous references in the Vedic literature that praise the medical values of trees and plants. Āyurveda is known as the fifth Veda of Atharvaveda. It is a medical science based on the knowledge and use of herbs and plants. From ancient times until today, āyurveda is commonly used for the treatment of diseases. The basic concept of āyurveda is the balance of the five elements (earth, water, heat, air and space) in the body. The body becomes ill when those elements are in imbalance. In order to bring the body back into equilibrium, different plants and herbs are prescribed. There are more than 100 plants mentioned in the Atharvaveda that are able to cure various diseases (Choudhury 1998b). The traditional Hindu knowledge of plants and trees included the management of important trees and is described in the Vrkṣāyurveda (*vṛrks*/tree).

Because of the fairly short period since the introduction of prosopis, there is no tradition of medical usage of the tree. In the present study, the only use of prosopis as medicine by villagers was found to be for the cure of injuries caused by the thorns of prosopis. Thus the prosopis tree does not rank equally with those indigenous trees that have been known to people for thousands of years for their medical powers.

The relation between humans and nature is experienced as a kind of partnership, not of exploitation or domination. A Vedic hymn addressed to *Kṣetra-pati* (lord/*pati*; of the field/*kṣetra*), where the spirit of the fields is asked to protect the fields and bless the farmer with a plentiful harvest, shows the special relation of agriculturalists with Mother Earth (*Ṛg-veda* IV.57). The Pongal festival in Tamil Nadu is an acknowledgement by the farmers to Mother Earth. Although nature may be cruel and inhospitable, it is also gentle and loving, but above all it is of immense importance.

In the Atharvaveda (Griffith 1895), water is praised as a healing entity that bestows health and wealth. Particularly, rivers are of specific significance for Hindus because they are believed to contain life-sustaining and purifying qualities. The river Ganges is one of the most holy rivers in India and for a Hindu believer to die at the banks of the Ganges brings immediate liberation, freeing the soul from the cycle of rebirth.

For Hindus, nature remains important and masses of people engage in pilgrimages to worship rivers, woodlands, mountains or sacred groves. Hindus believe that bringing gifts and prayers to sacred places purifies and cleanses away past sins and supports spiritual growth, which helps the aspirant on the way to final liberation (Choudhury 1998b).

6.3.2. Tree worship and rituals

Subtle and complex relationships between cultural codes and the natural world are experienced, articulated, and structured in ritual practices. People who depend on trees for their livelihoods use rituals and sacrifices to keep the tree's fertility vital. The sacredness of a tree grows with its age. As a tree becomes older, it is considered to have more sacred powers. A long history of devotion is believed to accumulate holiness in the tree and if the trunk is daubed with vermillion, its roots surrounded by gifts of devotees, or its branches decorated with flowers or prayer-beads, additional value is added to the tree. Respect is paid to old trees in places where the people assemble, because they are valued for their shade and beauty and also for their long presence and connection with the social life of the village. Although trees are liable to decay, a sapling that grows naturally or is

purposely planted on the place of the decayed original tree is considered to possess the unbroken power of the original tree (Crooke 1896).

Trees that are selected to be cut for religious purposes, such as to manufacture images of deities, for temple construction, or to make ritual utensils, are selected with care. In contemporary India, there are limitations in using sandalwood for cremation because of the scarcity of sandalwood trees. It is strictly prohibited to cut sacred trees, such as the bodhi or banyan tree, and even the pruning of branches is perceived as a sacrilege, an offence equal to the slaughter of a cow. However, if a sacred tree needs to be cut for a purpose related to temple activities or for carving of temple statues, a specific ritual is performed beforehand. This consists of the recitation of *mantras* (formulas of prayer) and the promise of a magnificent future for the tree because it will receive unlimited devotion from the devotees. Living beings, like birds or other animals, residing in the tree will be praised and propitiated also. Often, the tree spirits are calmed through offerings like ghee, betel or small coins placed on the stump. The felling of trees always causes a feeling of guilt; in earlier times, woodcutters were classified as belonging to the lowest groups in society (Nugteren 2005).

The veneration of trees is a form of *Shaktism*, the cult of the great mother. The deities that inhabit trees are offered food, cloth is tied to the branches and red-smeared stones are placed at the base of the tree. *Kōlam,* a ritual performed by women, indicates the mutual generosity that exists between nature and people and illustrates the social exchange between them. The daily creation of *kōlam* on thresholds, the ritual drawings or paintings of various rice flour designs in front of homes, on temples, or in front of trees, are the omnipresent signs of sacredness that can be seen all over India. It is believed that through the creation of a *kōlam,* the deity will be attracted to come and stay at the place and bless the home (Mazumdar and Mazumdar 1993). It is a common sight, especially in rural areas, to find crowds of people gathered around a bodhi tree that is decorated with garlands with a huge *kōlam* at its base, symbolizing devotion to the divinity residing in the tree (Nagarajan 2000).

Another ritual still practised in Tamil Nadu is the wedding of a human to a tree. The auspicious forces of the natural world are believed to be transferred to the individual through the practise of rituals of generosity, established with trees, rivers, or plants. Marrying trees is a ritual performed when there is a decrease in auspiciousness in a family. Infertility, illness, or the lack of a suitable partner for the son or daughter can be reasons for the marriage between a person, or a couple, and a tree. Hindus believe that trees have an enormous capacity to absorb suffering because of their abundance of auspiciousness and generosity. In cases of infertility, the natural fruitfulness of trees is believed to be transmitted to the couple. Thus, fertility in trees is able to encourage fertility in humans. In Tamil Nadu, banana and coconut trees are thought to have descended from heaven and are used as residences by various gods and goddesses. Their abundant production of fruits in clusters or bunches are the motivation for conducting marriages with those trees in order to create a desired relationship with auspicious elements in the natural world (Nagarajan 2000).

The two trees that are married can be different kinds but, usually, the procedure consists of wedding of a male and a female tree which are purposely bound together to become symbiotically intertwined. Often a bodhi tree and a neem tree are selected for those marriages, with the temple priest performing the ceremony. Either the two trees are planted very close to each other and married later or they are planted together in the same ditch and later tied together with a red wedding sari. Those trees especially attract women who hope for a happy conjugal life and progeny. Under the shade of the bodhi tree, prayers are made for male offspring and, traditionally, devout women veiled their face when passing it (Crooke 1896).

Another kind of tree marriage is the wedding between a man and a female tree or a woman and a male tree. A young girl, after reaching puberty, might be married to a male tree in the hope that the tree will channel its fertility into the girl and take care of her chastity. Often, the marriages between humans and trees precede the civil wedding. If a man has experienced two unlucky marriages ending in widowhood, the third marriage with a tree is believed to end his inauspiciousness. A man may also marry a tree he is especially dependent on, like toddy-tappers, honey gatherers, or latex-collectors, all depending on their respective trees, as a deed of honour and thanks towards the tree in question (Nugteren 2005).

Tree marriage is also performed for very concrete requests to the village gods. As recently as in 2009, in Coimbatore, in Tamil Nadu, the villagers of a nearby community performed a tree marriage between a neem tree and a banyan tree that grew beside each other for 35 years. The rite was performed to plead with the deities to stop the long lasting drought in the area and bring plenty of rainfall. Several hundred people were involved in the celebration (ANI 2009).

The present research in South India confirmed that although for Hindus everything in nature is sacred, there is a particular ranking and classification of trees. During the investigation, it became clear that particular trees have local appeal and are believed to be residences of locally known deities that protect the village. Those deities have different names in different places although worshipped with the same tree species. Other trees inherit spirits or gods known on the regional level, and the most sacred species have universal reverence. Trees that are regarded as most sacred are worshipped as abodes of the highest ranking deities and Hindu gods. The highest ranking sacred trees are not utilized except for purposes of worship. Other trees are regarded as sacred but are still used prudently for the preparation of medicines and even as building wood, as in the case of the sacred neem. Neem trees are also planted for the purpose of utilization. However, once a neem tree has been chosen as a place of worship, it will remain untouched by the villagers. The cutting of neem trees for utilization is always accompanied by prayers that aim to persuade the deity to abstain from punishing the wood-cutter (this was reported in a group discussion near Khumbakonam).

People plant trees for various purposes. As it is written in the Vedas, by planting a tree one earns the grace of god. Richer and higher caste people may plant bodhi or banyan trees on selected places to dedicate them to deities. Such trees might be decorated with clay figures or pictures of the deities and are additionally intended to provide shade for people. Under, or in close proximity of, sacred trees people feel the presence of the divine. They behave in a respectful manner, and the divine presence makes people speak only the truth. An influential British colonialist wanted to aquire good will among the people by planting a few bodhi trees around the marketplace of a busy town where traders used to discuss their business. However, to his surprise, the traders urged the man to desist from his plans. They argued that it belongs to the nature of their business to not always exactly tell the truth and the nearness of a bodhi tree would not allow those kinds of negotiations (Monier 1883).

In the present research area, there were many places where trees were planted by people who were grieving because of the loss of their beloved ones. They had planted them on burial grounds or other places where the deceased would be remembered. Often, people also worship trees when they are confronted with problems or questions that are beyond their perception. Worshipping the image of a tree is an aid and stimulus to awaken the spirit within the person. Devotees also come to thank the deity in the tree for the help they have received. Signs of thanksgiving and requests were visible on branches and around the trunks of trees. The women who came to ask for children tied small cradles on the branches and those who came to thank for the received child or children decorated the branches with garments of silk, mostly shawls (personal observation/communication). Those

garments were often of utmost beauty and value. When offering gifts or oblation to the gods, people do not pay attention to the price of the garment used for this purpose. Nothing is too expensive for the divine. Nobody would ever steal any of the valuable gifts hanging from the branches of sacred trees. They keep hanging there until their natural decay.

In the investigated region, farmers and landowners were reluctant to plant trees that are classified as most sacred, like the bodhi or banyan tree. One of the reasons for the farmers' reluctance was the size those trees achieve in old age. Since it is a taboo to utilize or harm them in any way, they can caste shade on a significant area of the agricultural land. Even cutting branches to avoid shading the crops might wake up the anger of the powerful deity residing in the tree. Interviewed villagers told that they will do everything to prevent anyone from harming those trees because they themselves might be punished by the deity or spirit for not protecting it.

Worship of trees in Hinduism symbolizes the various attribute of god in the image of a tree. It is believed that trees and plants possess internal consciousness and experience pleasures and pains (Bühler 1886). Through worshipping the tree, the devotee hopes for blessing from the gods or spirits that have their residence in that tree. Attributes like fertility and strength are desired to be transferred to the devotees, thus, granting an auspicious life. Monier (1883) reported incidents where trees were planted and confined to the protection of demons in the hope and belief that the spirit takes the responsibility for caring for the fruits of trees, thus, keeping away thieves from stealing.

In addition to the female goddess, which according to the present results made up the majority of tree deities in Tamil Nadu, there are male gods that are feared because they are believed to be powerful. When their anger is aroused they may cause great harm to the villagers. On the other hand, they protect the villages from powerful demons when treated in a proper way. To remain in favour of the warrior gods, people offer them blood sacrifices in the form of poultry, goats or sheep. This happens at least once a year during a huge celebration where the entire village participates or on several smaller occasions on auspicious days according to the traditions of that particular village.

Muneeswaram is one of those feared gods that was worshipped in the villages around Kumbakonam in Tamil Nadu. He is not associated with one particular tree species but may reside in sacred temple trees as well as in border trees at both entrances to the village. He is feared among women who would not go near the tree without the company of men. The reason for the choice of a particular village border tree by the deity is not fully known by the villagers. Most of such trees are more than one hundred years of age and people have continued to worship them for generations. What they do know is that someone from the village had once chosen a particular tree and, thus, the tree became sacralised and continued to be worshipped for generations to come. Should the tree be destroyed by a storm or biological factors, and if another tree started to grow in its place, the same deity would continue to reside in it (as was the case in Baruva village).

Both women and men who are believed to have the gift to be contacted by spirits and deities have the authority to choose the place and the tree in which a particular deity wants to be worshipped. As the examples from Andhra Pradesh show, the choice may also fall on a prosopis tree instead of the common indigenous sacred trees. If the deity that speaks through the villager demands a temple to be built beside the tree, it will be realized, as in the case of the deity *Centamony* outside Baruva village (see Chapter 5). However, the choice of prosopis is rather exceptional and only a few cases were observed where prosopis became a symbol of worship.

The observance of *dharma* requires humans to treat their environment with respect. However, *Advaita* philosophy allows a contradicting interpretation of the Hindu attitude towards nature. The tradition of Hindu non-dualism, also known as *Advaita* (nondualist) *Vedānta*, founded by *Śankara* around the eighth century B.C., supports attitudes of the neglect of the natural universe and actually devalues nature. The goal of the *Advaitin* is to attain a state of absolute independence where the spirit is not limited by the body, the mind, or the world of nature. The liberated soul is, then, able to realize true freedom (*jīvanmukti*). This experience of profound detachment from the world leads to oneness, which is seen as the highest truth where a human soul arrives at Brahman, the absolute. Consequently, only Brahman (god) is reality and the natural world is, therefore, unimportant. Thus, the divine cannot be affected by pollution and environmental degradation (Nelson 1998). Hinduism is very concerned about pollution but in essence it is more or less a concern about human purification, which is regulated by the caste laws of purity (Douglas 1966).

However, putting aside philosophy, the extend pollution and degradation of the environment in India depends on the huge amount of people, which amounted to more than one billion by 2010, and their need to make a living in an environment of increasing dwindling resources. The Indian environmental debate differs in essence from its Western counterpart. The West is contemplating the onset of the "post-industrial" economy, where for instance, forests slowly lose their importance for economic production but turn towards a becoming commodity that enhances the quality of life. In India on the contrast, the debates around the environment and forests are basically rooted in the question of the potential for increased production and energy supply (Gadgil and Guha 1992).

6.3.3. Impact of sacred trees on environmental protection

During the times when most of the religious Hindu literature was composed, the environment looked different, and there were probably enough resources that allowed people to extract nature in a prudent way. Hinduism has provided the basis for the protection of a distinguished number of *Ficus* trees and of entire ecosystems which today are preserved as sacred groves or sacred lakes. Due to their preservation, sacred forests contain many rare species, which are absent in degraded forest areas (Gadgil and Vartak 1975; Gadgil 1984). "The book of the forest" (Ganguli 1883-1896) also emphasises the beauty of the gardens with their plentiful flowering vines and herbs. The sacred gardens mentioned in the epics became the inspiration for worshipping nature in gardens around Hindu temples (Lee 2000; Lutgendorf 2000).

The beginning of the British colonial rule brought changes in the utilization of natural resources in India. Traditionally, forests were used mainly for non-timber forest products, but the British disregarded the indigenous ways of conservation in the form of sacred trees and sacred groves. The British rulers introduced the concept of scientific forestry based on the principle of sustainable yield. However, the over-exploitation of forests occurred because of using large amounts of timber to build railway tracks. Considerable areas of forests were cut to produce firewood and charcoal for railway engines and the industry. During the Second World War, from 1939 to 1945, vast areas of forests were cut down to supply the British war effort (Gadgil 1984).

As the present investigation shows, in Tamil Nadu, tree worship is still alive in the rural areas of India. Probably, the vision of Guru Maharaj Jambaji of the Bishnois, who declared the *khejri* (*Prosopis cineraria*) tree sacred, aimed at protecting the environment from degradation (Sankhala and Jackson 1985; Dwivedi 2000). In recent years, the Thar Desert in Rajasthan is densely populated and, due to the modernisation programs of the Government of India, grasslands have

diminished, giving way to plantations and agricultural irrigation schemes. Traditionally, the economy of the region was built on nomadic activities around grasslands and animal husbandry. Agriculture was only practised in times of adequate rainfall; otherwise people practised their traditional livestock herding and other occupations like handicrafts. Indigenous trees and shrubs like *khejri*, *jhaberi* (*Ziziphus nummularia*), or *sewan* (*Lasiurus sindicus*), were never cut or uprooted, not even on farmlands, because they provided fodder for the animals that ensured their livelihoods. Today, only the Bishnoi village farms in Rajasthan are still covered with *khejri* trees, of which women cut branches to feed their livestock (Sankhala and Jackson 1985).

The protection and prudent use of sacred trees plays an important role in the conservation of the environment. However, the growing population in India still depends on the important fuelwood on a daily basis. After the introduction of prosopis in Rajasthan, the tree was welcomed by the locals and used as a field boundary marker and for fuelwood. It averted a severe fuel shortage but people soon became aware of the negative influences, realizing that their indigenous *Prosopis* species (*P. cineraria*) posesses more advantages to support livelihioods than the foreign invader. On the other hand, they do not feel any discomfort in felling prosoips trees for their survival. Contrary to the use of the native *khejri*, which is regarded as sacred, the use of the "foreign" prosopis does not cause any dilemma. A wood collecting girl explained it in the following way:

> *"....as it is not a sin to kill a poisonous snake, it is no sin to cut the "foreign" tree"* (Binggeli 2001, 150).

The American anthropologist Ann Gold connects the replacement of the *khejri* trees by prosopis to the change in environmental politics that appeared during the last 50 years. After the power of the king of the Sawar region in Rajasthan expired, and with it the protection over the environment, degradation took its course. Today, prosopis is the only source of fuel in a region that during the times of the kings was classified as a region with dense jungles (Gold and Gujar 2002).

In present times, when pollution, climate change and a shortage of natural resources create pressures, especially in already resource-scarce arid and semi-arid regions, the first priority of people is to secure their daily needs for survival. If there is no other fuel source to cook the daily meal with, even sacred trees will go. The existence of prosopis offers people the opportunity to continue protecting their sacred groves and leave trees of worship untouched. The enthusiasm about prosopis at the beginning of its introduction has waned since the negative side effects of its invasion have become obvious. Nevertheless, as this study has shown, it has become an indispensible resource that is free for anyone to use.

6.4. Conflicts over trees and forests and potential solutions

6.4.1. General remarks

Trees and forests are such an important issue to Hindus that, over the course of time, conflicts between the government administration and local people over the use and protection of trees and forests could not be avoided. As it has been shown in this study, a fragile environment in combination with religious sentiments contains the potential for conflicts between people who are dependent on local resources and outside forces that use these resources to make profits that mostly are not shared with the locals. In the history of environmental conflicts in India there are two outstanding incidents that show how far people are ready to go when important natural resources are threatened. The two encounters are the struggle of the Bishnoi Community and the Chipko Andolan Movement, both of which have gained attention far outside the borders of India.

6.4.2. The Bishnois

The Bishnois are a small community in the state of Rajasthan with populations in the neighbouring states of Gujarat, Harayana, Punjab and Delhi. Environmental conservation is an integral part of their religious practises. The religion of the Bishnois belongs to a branch of Hinduism that was founded by Guru Maharaj Jambaji in 1451 A.D. in the Marwar area of the Thar Dessert. It is said that, from an early age, Jambaji observed and adored the surrounding nature. The appearance of continuing droughts caused degeneration of the area and the diminishing of livestock. Jambaji saw a connection between the cutting of trees, the uncontrolled grazing of animals, and the increasing desertification of the land. He renounced his inheritance and started his mission, teaching people how to protect their environment, enunciating 29 principles for living. His followers became known as the Bishnois, the "Twentyniners". According to those principles, Bishnois should restrain themselves from killing any animals, protect beneficial animals, and restrain from cutting any living tree. Over the decades, the area they occupied became covered with dense forests of large trees.

Some three hundred years later, in 1730, the Maharaja Ajit Singh, the king of Jodpur, planned to build a new palace for which he was in need of timber. He sent his soldiers to the Bishnoi village of Khejadali, about 30 km from Jodpur, to cut trees and transport them to the building place. When the soldiers did not listen to the protests of the villagers and proceeded to cut trees, a woman of the village, Amrita Devi, together with her three daughters, hugged the trees to protect them with their bodies. She and her three daughters sacrificed their lives to save the trees. This sacrifice did not stop the royal mission and the felling of trees continued. The Bishnois, then, decided that for any felled tree one volunteer would sacrifice his or her life. It is said that 363 Bishnois sacrificed their lives to honour their religious principles. When the Maharaja heard about the human tragedy, he ordered his soldiers back and apologised for the mistake committed by his officials. He also issued a royal decree stating that the cutting of green trees and hunting of animals within the boundaries of the Bishnoi communities are strictly forbidden. This order included the royal family and is still valid today (Sankhala and Jackson 1985; Dwivedi 1990).

6.4.3. The Chipko Andolan

Another, more recent event is the Chipko Andolan Movement. Chipko Andolan literally means the "movement to embrace". The movement started in the Uttarakhand region situated in the Himalayas, an area that is known for its beautiful mountains and valleys. The lives and livelihoods of the people in the region are dependent on its forests. Both sacred rivers, the Ganges and the Yamuna, pass through the mountain valleys to deliver water to the people living in the valleys. The forests provide protection from excessive soil erosion and maintain the physical balance of the ecosystem. A continous destruction of forests preceeded the flood of the Alakananda River in 1970, which had devastating consequences and cost the lives of hundreds of people. The floods were caused by the clearing of the mountain slopes (Bhatt 1990).

An organisation that represented the villagers in putting forward their demands to the government was formed and named Dashauli Gram Swarajya Sangh (DGSS). The co-operative organisation, which had its base and headquarters in the Chamoli District, played an important role in the Chipko Andolan. The Chipko Movement came into being in March 1973, when a commission of representatives and contractors of the Symonds Co., a sports factory, arrived in Gopeshwar. Their intention was to cut ash trees in the forest of Mandal, a few kilometres from Gopeshwar, which they had been granted permission for by the government. Before this, the villagers had been refused permission to fell and use trees for the production of agricultural tools. The commission was determined to go on with their intention to fell the permitted ash trees. On the same evening the villagers held a meeting where they decided that they would protect the trees by hugging them as a tiger mother would protect her cub by hugging the cub to her breast. The idea of embracing the trees, the birth of "Chipko", came from Chandi Prasad Bhatt. The protest was successful and the agents had to return empty handed to Gopeshwar (Guha 1989).

A new attempt by the contractors, who returned with a permit from the Forest Department, led to a confrontation between the villagers of Gopeshwar, who marched to the Mandal village, and the agents. About a hundred people hugged the marked trees, which forced the contractors to leave the forest again. As a result of the protest, the government gave in and cancelled the permit of the company. The trees were now officially assigned to Mandal village (Bhatt 1990).

In the aftermath of these early protests, another plot assigned by the government for felling trees was the Reni Forest, situated close to the town of Joshimath in the Alakananda Valley. This area had been suffering from landslides. After the villagers became aware of the threat and saw more than 2,000 trees marked to be cut down, they organised meetings and decided to adopt the Chipko technique to save the trees. While DGSS members and local men were participating in a demonstration organised in Joshimath, contractors travelled to Reni to start their felling operations. The presence of the male population in Joshimath gave them hope to be able to start their felling operations without disturbance. However, the contractors were spied and after their intentions were revealed, Gaura Devi, the leader of the village called Mahila Mandal, mobilized the women's club, and brought together quickly most of the women of Mandal who went out to protect their forest. The felling operation had to be cancelled, which marked another victory of the Chipko movement. This operation, for the first time, was organised and achieved by women (Guha 1989).

6.4.4. The aftermath of the Bishnoi and Chipko conflicts

The religious practices of the Bishnois have contributed to significant environmental preservation. Their principle is to utilize their natural resources to satisfy the community's daily needs but not for economic profit. The Bishnois connect their prudent environmental practices with religious sanctity. People of the community know that disregarding the principles laid down by Guru Maharaj Jambaji would be a sacrilegious act and would earn the displeasure of fellow community members. It would also make bad *karma* for the person, with consequences in the present and future life. That is why they do not fell any green tree and if twigs and small branches are used as animal feed they are cut with care not to harm the tree (Chaudhury 2006).

Today, the landscape surrounding the Bishnoi communities is flourishing with *khejri* trees. For them, *khejri* is the most sacred tree, believed to provide prosperity to families, as well as shade and fodder for their livestock. The black buck (*Antilope cervicapra*) was virtually wiped out half a century ago and survived only in a few small protected reserves. However, today the animal is found roaming around freely in the fields of the Bishnois, while the people perform their daily work in the fields nearby (Sankhala and Jackson 1985).

The Chipko Andalon has carried on its work against environmental degradation. The mother organisation of the Chipko Andolan, the Dasholi Gram Swarajya Mandal (DGSM), has continued to activate villagers to participate in afforestation and conservation practises. Camps are oganized by the organisation where villagers are taught about the sustainable use and protection of forests (Guha 1989). Protection of particular forests may be important due to environmental risks, like those found in forests of sensitive watershed areas, or because of religious traditions. Often, environmental protection and religious sentiments are at work simultaneously. In the contemporary state of Maharashtra, people of the Gani village contacted scientists to support their petition to conserve and protect their sacred grove near the village. The only perennial stream close to their village flows out of the sacred grove. The interference of the scientists in 1972 was successful and the Forest Department agreed to abstain from felling the trees and to spare the grove. Slightly astonished, one of the senior forest officials was wondering about the interest of the scientists and why they were bothered to protect these stands of "overmature timber" (Gadgil and Guha 1995). These conflicts highlighted the relation between religion, politics and the protection of forests.

6.4.5. Conflict solution in India today

Contemporary forest policies in India, as found in many parts of the world, classify forests in economic and ecological terms. Forest policies classify the forest lands according to their capability to grow plants and trees (soil quality, topography, etc.) in order to supply timber, NTFPs, or ecological services. The forest policy in India today also categorizes forests as productive forests, social forests, and protected forests (Chandrakanth and Fromm 1991). This exists alongside the unofficial, religious classification, which has important implications at the village level.

The current forest policy in India has undergone a major transition by changing the objectives of the management of the government-owned forests, from primary timber production and revenue generation to a policy of conservation to meet the subsistence needs of communities dependent on forests. The new policy also includes the protection and conservation of the biological diversity in sanctuaries, biosphere reserves and other protected areas. Watershed protection and the improvement of those important catchment areas is currently a central objective of India's national

and state forest policies. A social forestry programme aims at financially and technically assisting the planting of tree crops and fodder resources on community lands. The revenues generated through such programs are aimed to benefit the *panchayats* and local communities in order to provide incentives to them. It also considers giving ownership rights over trees to people from the poorer sections of society (such as landless labourers, small and marginal farmers, Scheduled Castes, Tribal Castes and women) or granting them usufruct rights to benefit from trees (National Forest Policy 1988; Chandrakanth and Romm 1991; Saigal *et al.* 2002).

Some of the Indian social forestry programs focus on the establishment of plantations through cooperation between the state's forestry administrations and the organizations of the village *panchyats*. Those projects can only succeed with the help of the villagers. Therefore, it would be important to design social forestry projects according to the classification people give to trees and places. This suggests that it would be most beneficial for all the parties involved if the villagers were allowed to select the location and the species according to their values. Projects should be adapted to the religious rites that people practice within the secular arrangements of social forestry projects (Chandrakanth and Romm 1991).

A new concept in the Indian forestry sector is to use market-based instruments for promoting sustainable forest management. One of the initiatives that has been developed in recent years is known as the "Bhopal-India Process", which aims to develop country-wide criteria and indicators for sustainable forest management. There, one of the objectives is to determine whether instruments based on a market economy might, for instance, enable the *ayurvedic* industry to contribute to the sustainable management of medicinal plants (Subrat *et al.* 2002).

The new Forest Policy is a step in the right direction. The main focus is on the devolution of power to the communities in order to enable them to care for their resources and to give them usufruct rights to forest products. Traditionally, nature conservation is a very ancient concept in India and has been practised on a community basis, especially in sacred groves. Those patches of forests have been almost completely unaffected by human interference, as can be concluded from the composition of the vegetation. These sacred groves often form climax forest formations and may range from a cluster of trees to as much as a few hundred hectars, often harbouring old and magnificent specimens of trees and climbers (Gadgil and Vartak 1975).

The northern limits of the gurjan tree (*Dipterocarpus indicus*) are found in a few sacred groves of Uttara Kannada in the Western Ghats. The Myristica swamp, which is a rare and threatened habitat in the south of Kerala, also has its northern limits in a sacred grove of Uttara Kannada. *Myristica magnifica* Bedd., a rare tree species, endemic to India, and *Pinanga dicksoni* Blume, a lean and beautiful endemic palm from the Western Ghats, are characteristic plants found in the swamp. In another sacred grove in the Maharashtra Ghats two magnificent specimens of the *Dhup* tree (*Canarium strictum* Roxb.) are preserved. Otherwise the species is only present in Uttara Kannada, which is situated a few hundred kilometres southwards (Gadgil and Chandran 1992). Sacred groves serve as last refuges for a huge variety of plants and also for various birds and mammals (Gadgil and Vartak 1975).

It is of utmost importance to preserve all the remaining sacred groves in India. Most of them belong to the government and are classified as lands reserved for temples. In some cases, the groves have been handed over to the Forest Department and classified as preservation plots. In this way, those groves gain legal protection in addition to the protection through religious motives. However, there are still privately-owned sacred groves that need to be transferred into the hands of the Forest

Department or to be taken care of by the communities surrounding those forests (Gadgil and Vartak 1975).

Despite the conservationist aspects of sacred groves, they are also of economic significance. Groves have become the last refuge for many plant species that possess medicinal properties. The study and sustainable use of these resources may prove to be of considerable economic value for the livelihoods of many people surrounding those forests. Studies connected with sacred groves (as well as this study) revealed that the reasons why people abide by the taboos forbidding the exploitation of forest goods in the sacred grounds of the gods is that those gods are vengeful. The fear of reprisals from the deities when violating the rules of prudent use of the forests provides protection against the over-use of the groves (Kent 2009).

However, changes in the structure and composition of society and changes in religious values pose threats to sacred groves. As research in the tribal communities of Meghalaya in northeast India has indicated, the majority of younger people considered religious beliefs in connection with sacred groves as superstition. Further, a significant number of tribal people have converted to Christianity, with the consequence that many tribes have become disinterested in performing the traditional rites, rituals and ceremonies associated with sacred groves (Tiwari *et al.* 1998). Another threat leading to the desecration of sacred groves lies in the increasing urbanisation, which increasingly causes the dilution of cultural and religious values (Ormsby and Bhagwat 2010). Most of the literature connects sacred groves in India with the Hindu religion. In fact, rites and ceremonies, as well as the protection of these sacred sites, date far back before the event of the Brahmanical tradition and existed alongside Hinduism as part of a religio-cultural landscape. The Brahmanic priests merely institutionalized the sacred groves and brought them under the patronage of the Brahmanic temples (Tomalin 2004). Nevertheless, Muslims and Christians, for instance, do not share the same cultural and spiritual values connected to tree worship with the majority of Hindus (Ormsby and Bhagwat 2010).

7. Conclusions and recommendations

This thesis is about the interaction of culture and nature. Hindus experience nature as a holistic union, with humans as one part in it.The findings in this research discussed how Hindus classify the trees in their environment. Thus, indigenous trees like bodhi, banyan, or neem rank on top of the scale of appreciation. Prosopis is perceived as an "outsider" and does not gain equal respect from people. As the investigation revealed, after the appearance of prosopis in the arid regions of South India, people and nature adapted to the exotic newcomer. There are several ways in which people have learned to make use of prosopis. However, some potentials of the tree are still not utilized, partly because of the low position prosopis inhabits in the classification ranking. Further, the research discussed the dangerous consequences that an uncontrolled invasion of prosopis could cause to the environment, referring to experiences in other parts of the world.

The Hindu culture in India is significantly shaped by religious values. This influence can be experienced especially in rural villages. While the large towns and industrial centres of the country are changing towards a Western style of life, for hundreds of millions of rural people, the ethical and religious values that have been handed down from generation to generation are still alive today and play an important role in their daily life. For Hindus, it is the sacred that always counts most when compared with the profane. As the classification of trees shows, the most appreciated are those species that are classified as abodes of deities. Prosopis, on the other hand, is most useful to millions of people although it is classified far at the bottom of the ranking list. The more the negative impact of prosopis invasions becomes obvious, the less the resource will be appreciated. However, the tree has come to India to stay, and if managed in a proper manner, it can continue to be a very important natural resource for many of the poorest people.

The scenario for the future indicates that the world will face a heightened battle over natural resources. There will be winners and losers. It is predictable that the gap will widen between people who have access to resources and those who are unable to get their fair share. The benefits achieved by rural people in the drylands of India through the utilization of prosopis seem rather minor in comparison with the overall global demand for natural resources. However, for those people and families in the drought-affected arid and semi-arid zones, even the smallest help can be crucial for their survival. In South India, and in India in general, there are millions of rural people for whom prosopis is the only source of energy and income. Trees that grow on government wasteland are free to be used by anyone. As the study has indicated, there is still the potential to improve the exploitation of prosopis through proper management practices that increase its beneficial utilisation. The establishment of sawmilling enterprises in combination with the creation of new markets for value-added products has the potential to create new jobs in areas where paid labour is scarce. This would also support the economy of many rural communities by creating new opportunities to increase assets and diversify the family income.

The worst scenario of a further uncontrolled invasion of prosopis, on the other hand, aggravates the danger of ecological degradation, which would obviously be followed by economic losses. Today, there are people who benefit from prosopis and farmers who experience threats to crop production due to the invasion of the plant. If farmers face a situation where agriculture is not anymore a profitable undertaking because of reccurring droughts, followed by prosopis invasions, even more people would suffer and lose their jobs in agriculture. A balance between the two extremes of eradication and increased invasion, combined with adequate management intervention, seems to be the best solution.

Results from research on the management of exotic *Prosopis* species are available today on a wide scale. In the case of India, the time for implementating methods for controlling invasions and increasing the useful potential of the tree is precious. In only a few decades from now, interventions will become more difficult and expensive. Interventions need to be well-prepared and the involvement of the Forest Departments and the state governments are crucial. The potential for the manufacture of value added products, and the quality of prosopis wood for such products like furniture and roofings, needs to be explained to villagers. This could be a task arranged by the *panchayats* and the agricultural extension services, backed up by the responsible government institutions. Their task would also be the planning and implementation of invasion control.

A great potential of prosopis that is still not utilised on a large scale, and still needs testing, is found in rehabilitating of degraded soils and converting them into agricultural farmlands. Experiments made in many places around the tropical world have shown promising results. Proper management of prosopis that now grows on fallow government land could lead to the convertion of unproductive soils into new agricultural lands for a growing population.

It is important to understand the culture and religion of India in order to intervene and support people in their use of natural resources. While in many countries in the developed world, trees and forests are planted, managed and taken care of mainly for the sake of economic gain, in India nature in general, and trees and forests in particular, have a very different meaning. However, this does not exclude the utilization of natural resources. It is more a question of values: sacred first, profane thereafter.

Trees regarded as sacred by Hindus are protected and may be exploited only to a minimum extent, for instance, for preparing medicines. Trees on temple grounds, or trees that are believed to be inhabited by Hindu deities, are not allowed to be touched at all. However, when fuelwood is not availlable, people are forced to use those resources. The presence of the exotic prosopis allows people to keep their traditional sacred trees, since they are able to use the abundant newcomer for their most urgent livelihood need, the need for fuelwood.

The results revealed that prosopis takes its place at the bottom of the classification scale. Although it is appreciated as a source of fuelwood for the poorest of society, its appreciation as wood for furniture or other value-added wood products is very low in India. Even today, it is called “the foreign tree” in many areas. Work needs to be done to convince people of the potential of prosopis timber and to manufacture and market new wood products using prosopis as a raw material. Experience from elsewhere, for instance the U.S., supports this initiative.

In comparing people’s perceptions of prosopis in the Sudan with those in South India, some significant differences are apparent. While people in the Sudan heavily disapprove of the existence of the tree in areas where there are dense invasions, people in South India tolerate the tree and appreciate its services to the poor. However, the mood of people in India might change if the invasion cannot be controlled. Also, the fact that farmers in India commonly own their fields makes control of prosopis invasions easier. Still, if reccuring droughts hinder, limit or make crop cultivation impossible, as occured during the first years of the new millennium, farmers need guidance and support in controlling prosopis, especially in the case of invasion onto fallow land.

There is a need for an assessment of the present situation of prosopis invasions in the drylands of India. Geoinformation data, such as satellite images and areal photographs, are easily available, especially since India maintains its own satellites. In areas where eradication of prosopis is necessary, there is a need to plan ahead for proper management practices after the eradication has

been completed. Strict control of seedlings emerging from the soil seed bank is of utmost importance. In addition, trials need to be undertaken to identify indigenous species suitable as a replacement for the prosopis trees. The shading effect caused by the planted trees would prevent prosopis seedlings from growing and the new species could ensure a continued wood resource in the future.

A task that needs to be accomplished soon is to investigate and map to what extent prosopis has already invaded sacred groves or other protected forest areas and to take measures that stop further invasions. To keep those places free from prosopis or any other invasive species is not only important because it keeps the area vital for religious practises, but also because it conserves the rich biodiversity that can be found in those forest patches. Further studies of the conservation of medicinal plants in sacred groves and their sustainable extraction would support the development of economic benefits and employment opportunities for the people living close to those forests. Conserving sacred groves would thus ensure that future generations will be able to learn and benefit from those islands of floristic richness.

In forest policies for India, it is and will increasingly be important to understand and read the codes for forests in India that are deep-rooted in the history, landscape, and culture of the country. Maybe, more than anywhere else in the world, these policies need to acknowledge the religious sentiments and motives that prevail among people at the local level concerning forest resources. The success in forest management depends on the willingness of the local people to take care of their land. The success of social forestry and the future for the millions of people who depend on forest resources for their livelihoods are connected to the recognition and respect towards the religious values of the local people when planning or implementing forest management practices. The example of South India shows that people are still deeply anchored in traditional beliefs about trees and forests.

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Interviews of officials

Murthy, V.B.R. National Forest Department. Conservator of forests. Interview 8/07/2005, Hyderabad, Andhra Pradesh.

Pullaiah, T. University of Anantapur, Taxonomist, Professor in Plant Sciences. Interview 22/07/2005, Anantapur, Andhra Pradesh.

APPENDIX 1: Questionnaire (Data collection in Andhra Pradesh)

(Modified after field test)

Date:
Name of district, village
Size of village:
Local language:

(I) Background information:

1. (Name), sex, age, education
2. Ethnic group, caste (religion)
3. Occupation (what work are you doing today, before?)
4. Is the village your native place (parents); if not, where did you come from; why?
5. Household: how many children, who else is living in your family?

(II) Agriculture

1. Do you own the land you cultivate? If yes, did you inherit, buy?
2. How big is the land; what crops do you cultivate; which crop in which month?
3. Which are cash crops, which for subsistence?
4. How much can you annually earn from agriculture?
5. Do you get sufficient water? What is your water source? If bore well, when did you build for what cost (did you need to take a loan?) When do you experience water shortcuts (which months), how much do you spend for water supply (if other source)?
6. Same questions for electricity.
7. Do you use fertilizers?
8. How much money do you need for all field preparations (incl. seeds)?
9. Do you employ labour for fieldwork in season? How many people? What is their daily salary? What do your employees do in off season?
10. Are your wife and children helping in fieldwork?
11. How many days a week/ hours per day do you work on your field? (At the time of preparing and planting the crops/ in harvesting time?)
12. How do you spend the off-season time?
13. Do you keep prosopis as bio-fence? Did prosopis appear naturally or did you plant seedlings?
14. Do you need to clean prosopis from your field? Do you tender the trees in case they start shading crops? How much time do you spend monthly for treating prosopis?

(III) Livestock:

1. How much livestock do you have (kind of animals, number)?
2. What is the purpose of keeping livestock? (working animals, sale on market, own consumption).
3. Are your animals grazing on prosopis pods? Do you collect pods for feed in scarce times?
4. What is the condition of your livestock (own opinion), compared to e.g. 10 years ago?
5. Do you sell milk, own use, how much daily?
6. How much money do you need to spend for keeping livestock?

7. Any veterinarian practising close by? How do you treat your animals in case of sickness? Is livestock in general healthy?

(IV) Fuel consumption

1. What is your main source of fuel? (gas, charcoal, firewood, combinations)
2. How much do you use prosopis as firewood (bundles/day); who collects it; how much time is needed for daily collecting?
3. Do you sell prosopis firewood?
    - if yes: how much, for what price, too whom?

(V) Opinions about prosopis and environment

1. Do you think prosopis is a useful tree? useful for which purposes?
2. What do you use prosopis for (shelter belt; house fencing material; pods etc.)
3. Has prosopis increased during the last years? When did you start observing the tree?
4. Did you or any of your family get injuries from prosopis? How do you cure injuries?
5. Do you think that prosopis has any influence on protecting your soil from erosion?
6. Are trees important for you? For which purposes? Which trees do you appreciate most?
7. Do you know about trees being used for medical purposes? Which trees? For what kind of diseases?
8. Do you know anybody in the village who is collecting leaves, roots, flowers or fruits from trees or plants to prepare medicines?
9. Has the environment degraded during the last years, according to your opinion? Why, what do you think are the reasons? What could be done to improve the environment?

(VI) General questions about social life

1. Do you prefer to live in this village? Why?
2. Could you imagine migrating to city if agriculture becomes insufficient to supply your family?
3. How is the general health in your family? Do you often need to consult a doctor? Where is the next health care? Do you easily get medication here?
4. How is the drinking water situation? Do you have bore wells? How do you estimate the ground water level?
5. Are your kids going to school? Which grades? Is schooling free?
6. What are the chances for employment after school? How do you estimate the future of your children?
7. How is the employment situation in your village?
8. How many hours do you work daily? How many days weekly (in season; in off-season)?
9. When do you take leisure? How do you spend your free time (with family, alone)?
10. Are you able to safe any money from your income? How do you use your savings?
11. Do you get any remittances from family members who live outside the village (e.g. abroad, in big towns etc.)?

APPENDIX 2: Questions to forest officials in Hyderabad.

1. Which is the organisation you are working for (ministry, commune, state)?
2. Are there statistical figures on employees in forestry available?
3. What is the role of private sector forestry in Andhra Pradesh?
4. What are the main activities of the Forest Department in Andhra Pradesh?
5. Do you have any statistical figures on tree planting and management in Andhra Pradesh
6. Which are the most precious trees in the region (possibly ranking)?
7. What is your policy for the use of firewood trees (which trees are allowed to use, which ones not)?

Prosopis:

8. Are you promoting any plantations of prosopis?
9. Are there any restrictions in the use of prosopis (cutting trees, selling etc.)?
10. Do you have any (possibly ongoing) research on prospis (growth figures, biomass, pods etc.)?
11. How did you observe the growth of prosopis during the last 20 years (any increase)?
12. What role does prosopis play in forestry (is it promoted, how? just left as it is? any future plans)?
13. How do you see the future possibilities of prosopis for the forestry sector, for the people?
14. What are your opinions on prosopis (use, possibilities, threats)?
15. What is your knowledge on the multiple uses of prosopis (any reports on use in medicine or ayurvedic industry)?
16. Did you get any complaints from farmers etc. because of prosopis (occupying land, causing injuries etc.)?
17. What is the general opinion of people about prosopis (to your official knowledge)?

Personal opinions on prosopis:

18. What is your personal view about prosopis?
19. Do you think prosopis has any impact on improving livelihood in Andhra Pradesh?
20. How do you see the future of prosopis in Andhra Pradesh and India?
21. Do you think my present research can have any impact on the way prosopis is presently dealt with?

General views:

22. How will the forestry sector develop in future?
23. What role does forestry play in the reduction of poverty and maintaining of livelihood of the rural people in Andhra Pradesh?
24. What are the lessons learned from the past?

APPENDIX 3: Questionnaire, Tamil Nadu, Dec. 2008 → Jan. 2009

Background information:

1. Name
2. Sex
3. Religion (caste)
4. Age
5. Education
6. Household size

Qualifying trees:

7. Which are the trees you know in your surroundings?
8. Do you know any other trees (mention also trees classified as sacred)?
9. Which trees are ranking highest in your opinion, second, third etc.?
10. How do you use trees (fencing, building materials, furniture, fruits, firewood, charcoal)?
11. Thinking of medicine (ayurveda) which tree species come into your mind?
12. Do you know specific sicknesses which are cured using trees (which part of the tree for the cure of which sickness)?
13. Do you think trees are sacred? Which ones? Why?
14. What does a tree symbolize for you (fertility, strength, power, etc.)?

Prosopis

15. Where do you rank prosopis compared to indigenous Indian trees (e.g. the one you mentioned)?
16. Do you use prosopis (how) and what do you think is the best use of the tree (for whom)?
17. Could you imagine prosopis having the status of a sacred tree?
18. Do you know the origin of the tree (how and when did it come to India)?
19. (In case of invasion) Do you think prosopis should be eradicated?

Trees& forests:

20. Do you think forests are important and why (are they?)?
21. Should people be aloud to use forest products (NTFP, fuelwood)?
22. Which products do you use from forests?
23. Did you ever plant a tree (which species)?

Agriculture:

24. Describe your agrarian cycle, starting from ploughing (agriculture needs to be studied in detail → rituals, leisure time, crop cycles, water resources, present and future of agriculture etc.).

Rituals:

25. Do you perform any rituals in your home, connected to agriculture, trees (daily, sometimes, in regular intervals); what purpose do rituals serve in your opinion?
26. Do you think rituals are important (who taught you about them)?
27. Have you heard of the ritual practice of marrying trees with each other, or humans and trees? What do you think about it?
28. Do you know about deities living in trees? What is their purpose (protection)?

Environment:

29. How has the environment changed during the last years (degraded, same as before, or improved)?
30. What do you think are the reasons for the changes? What should (could) be done?
31. Do you think that Hindu religion has any influence on the behaviour of people towards their environment? (Does it influence your behaviour?)
32. Where did you get your knowledge, regarding nature, from (school, home, from literature)?

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