CHAPTER 10

ON-SITE TRIAL FOR CONSERVATION AGRICULTURE WITH LOCAL RESOURCES

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Project Objective

As shown in the "Introduction", Japan International Research Center for Agricultural Sciences (JIRCAS), Ministry of Natural Resources, Environment and Tourism (MNRET), the Environmental Quality Protection Board (EQPB) and the Palau Community College (PCC), conducted a series of studies under the research project titled, "Development of Sustainable Resources Management System in Palau" from fiscal year 2016 to 2020 under a project concept as shown in Fig. 41.

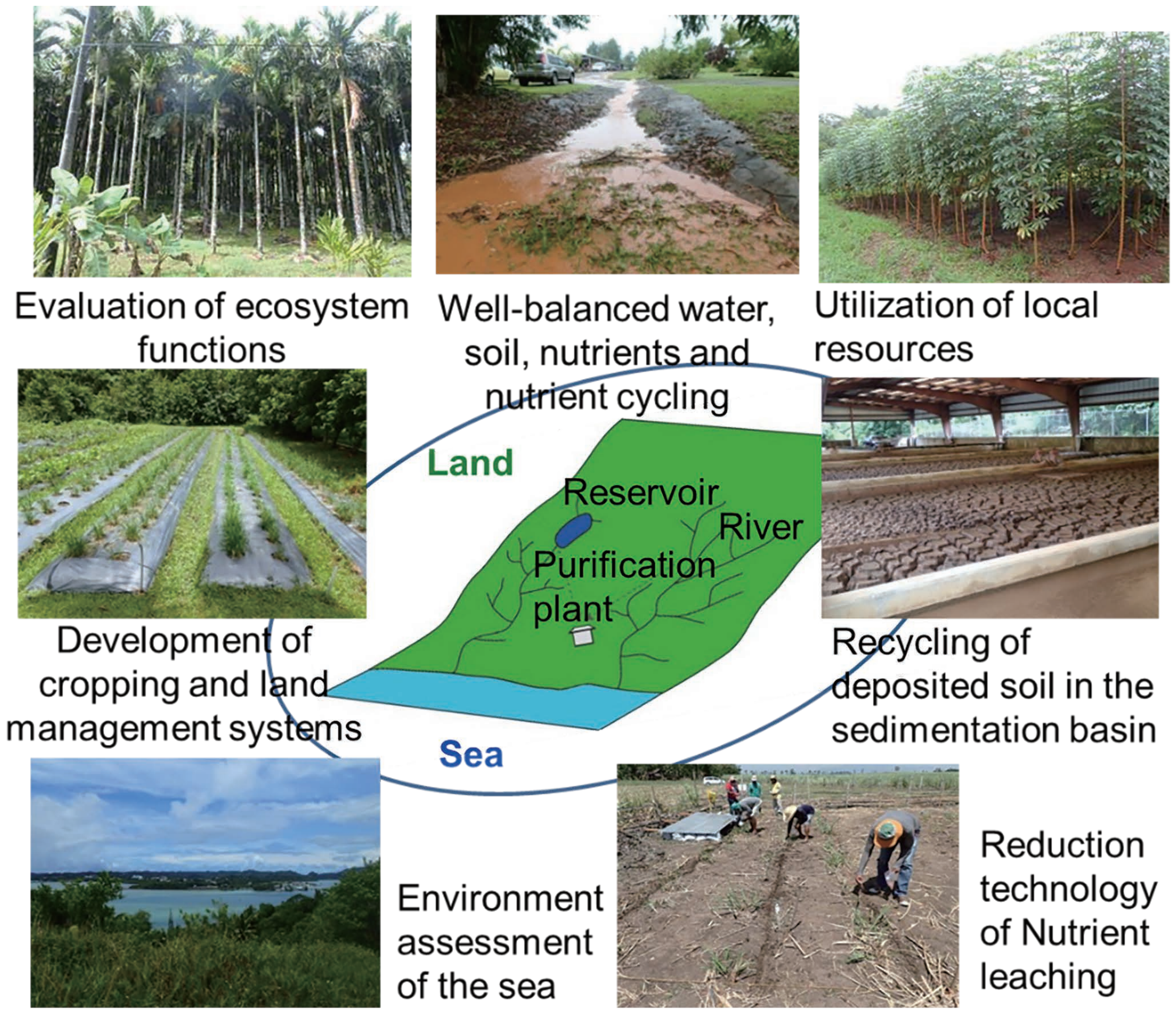

Fig. 41. Project concept of natural resources management in humid island

In prior to conducting the research activities, we conducted a paper review and investigated the current agricultural situation in Palau.

As indicated in Chapter 2, the Palauan landscape was altered severely by foreign contacts, governmental policy development and so on. For example, vast areas of landscape were disturbed and altered for coconut plantations and trading posts during the 1800's (Hezel and Berg, 1979). The same situation was repeated in German era (1899-1919), too (Spennemann, 1999). Agricultural, mining and fishing activity peaked during the Japanese period (Peattie, 1988). From 1947 to 2006, 39.24 km2 of deforested area was reforested but 30.46 km2 area of them still remains as grass or bare land (Iida et al., 2011). Those grass or bare land are currently used for development of infrastructure, new residential areas and commercial agriculture with less regard for the environment. As the results of vegetation removed, discarded soil by urbanization reached the sea and eroded soil covered coral, coral cover decreased from 80 to 40% in the decade. We observed that some parts of the eroded soil came from sloping agriculture fields at Ngerikiil watershed, Palau in 2016 (Fig. 42). From these observations, we were sure that eco-friendly production and land management is necessary and have to be developed in the project.

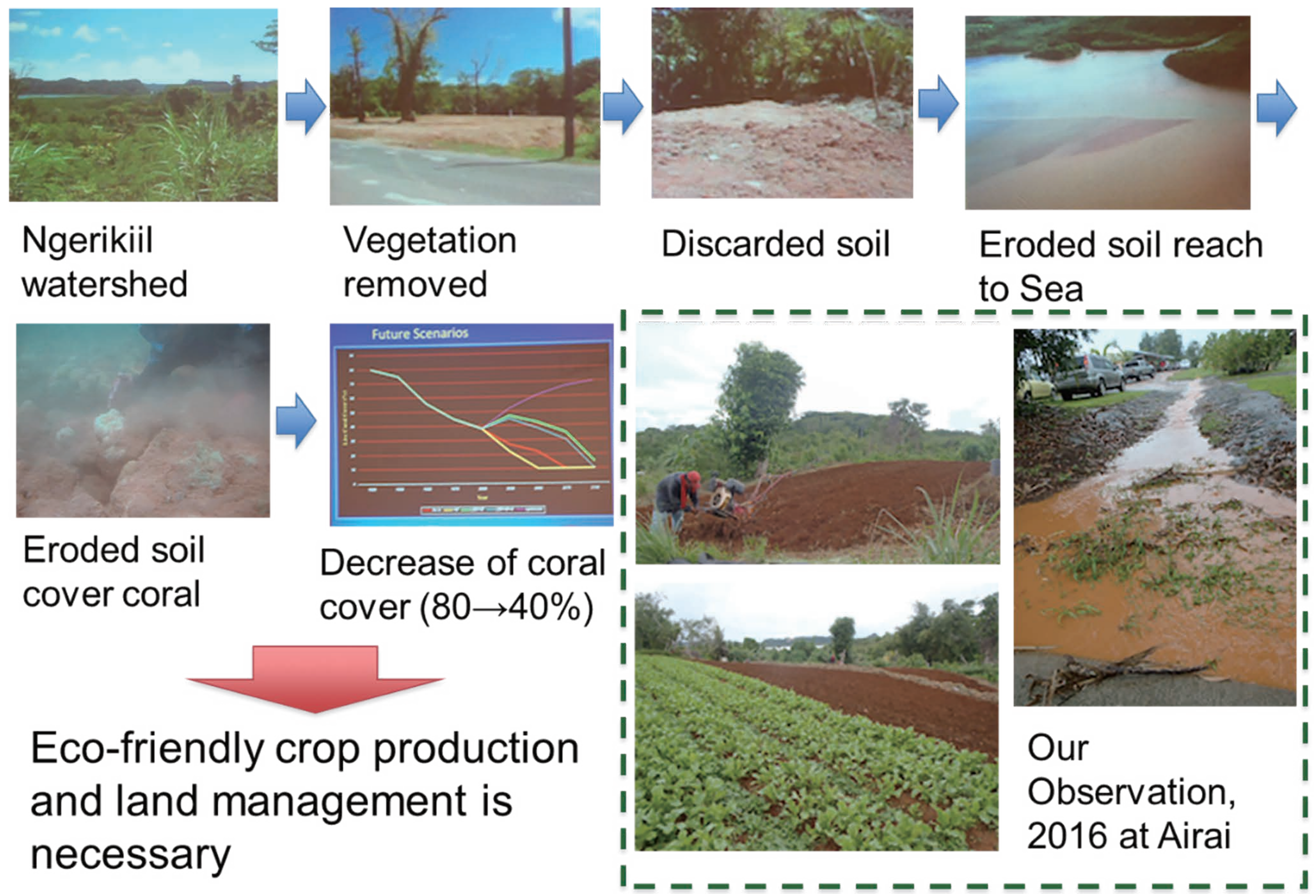

Fig.42. Current watershed situation and our trial in the project

Agricultural Background in Palau

Palauan villages were traditionally designed to fit the natural landscape in order to guarantee sustainable harvest of food and drinking water (Fig. 3). Traditional agriculture is good for people and the environment (See Traditional agriculture in Chapter 4). Palau's traditional agriculture is a multi-story agroforestry, where tree crops provided a protective canopy for the intensive production of over 40 plant varieties. The agroforestry system included the wetland taro agriculture, mixed tree gardening, backyard or kitchen gardens, and intermittent (shifting cultivation) tree gardening and open canopy culture (OTA, 1987). The traditional Palauan farming method, agroforestry has proven to be sustainable with food production for generations since it is the farming practice as it involves minimal soil disturbance maximum organic matter input for countermeasure against soil erosion (See Agroforestry in Chapter 9), All areas of agroforestry are maintained by covered with plants or organic mulch that are good to prevent soil erosion. As results of traditional practices, research shows taro patches can absorb up to 90 percent of sediment and thus protect Palau's coral reef (Koshiba et al., 2015). Results of the survey on the spatial structure and landscape of traditional villages and living habitats of the village people indicated that the traditional structure and lifestyles still remain at some parts in villages of Babeldaob Island (Iida, 2011). However, climate change increasingly impacts food security. On average 6 percent of taro production is lost each year due to saltwater intrusion (Del Rosario et al., 2015). OERC reports that local food production declined by 5% during the severe drought of 1997-1998 (OERC, 2008). Despite efforts to rehabilitate taro patches and promote salt and drought resistant crops, climate change continues to pose challenges to food security (SOE 2019).

The landscape of Palau is a medium to low volcanic island chain with large fringing and/or barrier reefs. The Palauan island chain has all three-island types: volcanic, limestone and atolls. Despite being the closest Micronesian island to larger land masses, Palau is still relatively isolated. Due to these factors, Palau has the greatest number of endemics and highest species richness in the Micronesian island chain (Canfield, 1981). This ecological significance and archeological features of limestone rock islands were deciding factors in the Rock Islands southern lagoon's nomination as a UNESCO World heritage site in 2012 (Reepmeyer et al., 2011). This nomination pushed up foreign tourists to visit Palau and increase the demand for local products by the hotels and restaurants.

As mentioned the above, there has been a changing nowadays trend in the increased consumption of food products which could be attributed to increase in population, the promotion on the use of local, nutritious food, the increase in demand for local produce by the hotels and restaurants, the dramatic increase in price of imported food items and climate change influences. There is less wetland taro cultivation today than in the past (Hunter-Anderson 1984). Reasons for the abandonment of wetland taro include higher labor and time costs of production, altered consumption patterns (in particular, the increasing dependence on imported starches), typhoon and pest damage to taro, government encouragement of cassava and sweet potatoes production to alleviate the shortage of Colocasia (McCutcheon 1981), the time and labor constraints associated with an urban lifestyle (Hunter-Anderson 1984), and the attractive of the modernization. As a result, 27% of them employ foreign labor to assist in the production of taro, which is an important crop culturally and economically, as well as for subsistence purposes (Nwe et al., unpublished data).

The situation of current agricultural production in Palau is, thus, below the self-sufficiency line (FAO, 2008). Palau imports 85% of food products consumed. Palau is a popular sightseeing destination and rich in culture. Because of focus on tourism and its dependence on imports, potential complications will arise if global markets collapse. Share of the domestic food production decreased significantly and that has been worried for more than 20 years. The Palau government is trying to increase domestic food products such as taro. Palau households were least reliant on subsistence farming, with only 9% of households reporting this as their main livelihood resource and lowest compared to other island nations in the Pacific. If the shipping that sends imported food products stops, Palau will have a food shortage. Self-sufficiency in the agricultural sector is the challenge for food security.

We investigated the current agricultural situation and background of food demand in Palau, and summarized a potential and constraint for agricultural production in Palau as shown in Fig. 43.

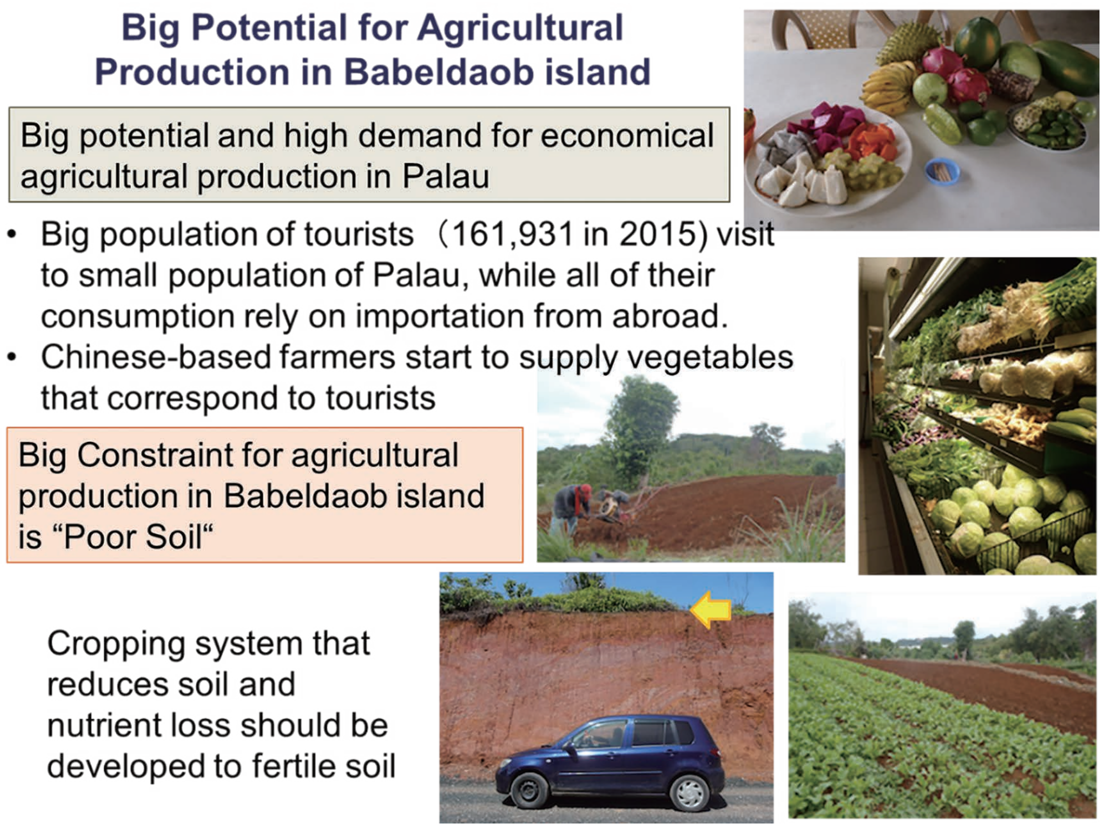

Fig. 43. Potential and constraint for agricultural production in Babeldaob island, Palau

Land selection to conduct the project activities

As a next step of our activities in Palau, we surveyed technical constraints for agricultural production in Palau and decided target technologies which should be developed during the project.

As mentioned in the above, traditional agriculture including taro patches and agroforestry is good for people and the environment (See Traditional agriculture in Chapter 4). The traditional Palauan farming method, agroforestry has proven to be sustainable with food production for generations since it is the farming practice as it involves minimal soil disturbance maximum organic matter input for countermeasure against soil erosion (See Agroforestry in Chapter 8), All areas of agroforestry are maintained by covered with plants or organic mulch that are good to prevent soil erosion. So, to the extent of the traditional taro patch and agroforestry system, we do not need to do any actions for them. These systems are already eco-friendly and high productivity except the problems for salt intrusion and shortage of the labor.

When we look at the mountainous direction, we can find a large sloping area that still remains as a grassland (Fig. 8 and 11) after the exploitation during World War II by Japanese immigrants. If we can develop a technology to use this area for agricultural production in an eco-friendly way, we can promote agriculture production and enhance food security without disturbing the rich environment in Palau. However, we found several constraints to these grass lands after the review and local survey. These constraints are clarified from aspects of slope steepness, soil fertility, water availability and management as in Chapter 6 (Constraints for agriculture development). At the next step, we classified the lands from the aspects of future possibility of crop production with consideration of the constraints in Chapter 7 (Map for agricultural development). In Chapter 7, We proposed four prospective areas to be used for agricultural development such as 1: Recommendable for agriculture, 2: Recommendable for agriculture with attention to soil erosion, 3: Soil amendment required for agriculture, and 4: Recommendable for agroforestry with attention to deforestation.

We, then, selected Category 3 (Soil amendment required for agriculture) for the area where we should focus because of the difficulty and conducted the project activities to develop new cultivation technologies that promote agriculture production and enhance food security with eco-friendly ways in Palau. The difficulty of conducting the activity in category 3 is caused mainly by two factors; slope steepness and poor soil nutrition that are summarized in Chapter 6 (Constraints for agriculture development). Technical perspective to conquer these difficulties are summarized in Chapter 8 (Technical perspective for future crop production) and Chapter 9 (Technical perspective for future fruit tree production) with information of selection of fruit trees and varieties, propagation and pruning of fruit trees.

Selection of the technologies to be developed

After the discussion among the members, we decided two subjects which the project will handle as follows below:

1. Construction of well-balanced water, soil, nutrients and nutrient cycling, and evaluation of ecosystem functions in watershed of the Babeldaob Island

2. Development of sustainable cropping and land management systems with utilization of local resources.

In subject 1, we focused the deposited soil in the sedimentation/sand basin to use for agriculture production in order to improve soil nutrition. In subject 2, A cropping system that reduces soil and nutrient loss into the river was developed and proposed. A land management system was also developed through utilization of local resources such as crops and fruit trees by the activities.

Technologies developed in the project for improvement of the soil fertility

We considered that conservation agriculture may be one of the answers to rely on the project demand. Conservation agriculture, composed of three principles, minimum soil disturbance, permanent residue cover, and diverse rotations, is suggested to be the best management practice for improving nutrient cycles and soil organic matter restoration, increasing available soil water, and controlling erosion (Hobbs, 2007; Hobbs et al., 2008; Reicosky & Saxton, 2007). In Palau, and many other small pacific islands, erosion and sedimentation are more serious in steep topography, highly erodible young volcanic soils under high rainfall. According to a soil survey by USDA (2009) in Palau, Infertile poor organic matter containing very acidic red iron and aluminum-rich oxisols is dominant in the subsoil of the steep upland of Babeldaob Island. Those constraints make large-scale agriculture very difficult without proper amendment except for swamp where taro was traditionally produced (Smith and Babik, 1988; USDA, 2009; Deenik, 2011). In swamp, organic materials are traditionally used both as mulch and for soil amendment that are collected through the traditional agroforestry system. Use of organic mulch, therefore, can be an option to introduce as conservation agriculture in the steep upland. In addition, amendment of sub-soil by use of a mechanical hand drill or trencher also can be other options to minimize soil disturbance, support shortage of young hard-workers, and to promote crop root development to increase the yield. Furthermore, we could find sedimentation in the water reservoir in Palau. This deposited soil in the reservoir can also be another choice to use in agricultural land for soil amendment. In prior to transferring most effective technologies to Palau, we, at first, have tried to develop sustainable technologies to be disseminated in Palau with artificial sloping fields in Ishigaki, Okinawa, Japan for 2 years.

After the development of the technologies in Ishigaki, we have transferred the technologies to Palau for verification and demonstration for another 3 years. The background of the agricultural situation in Palau and possible solutions are summarized as in Fig. 44.

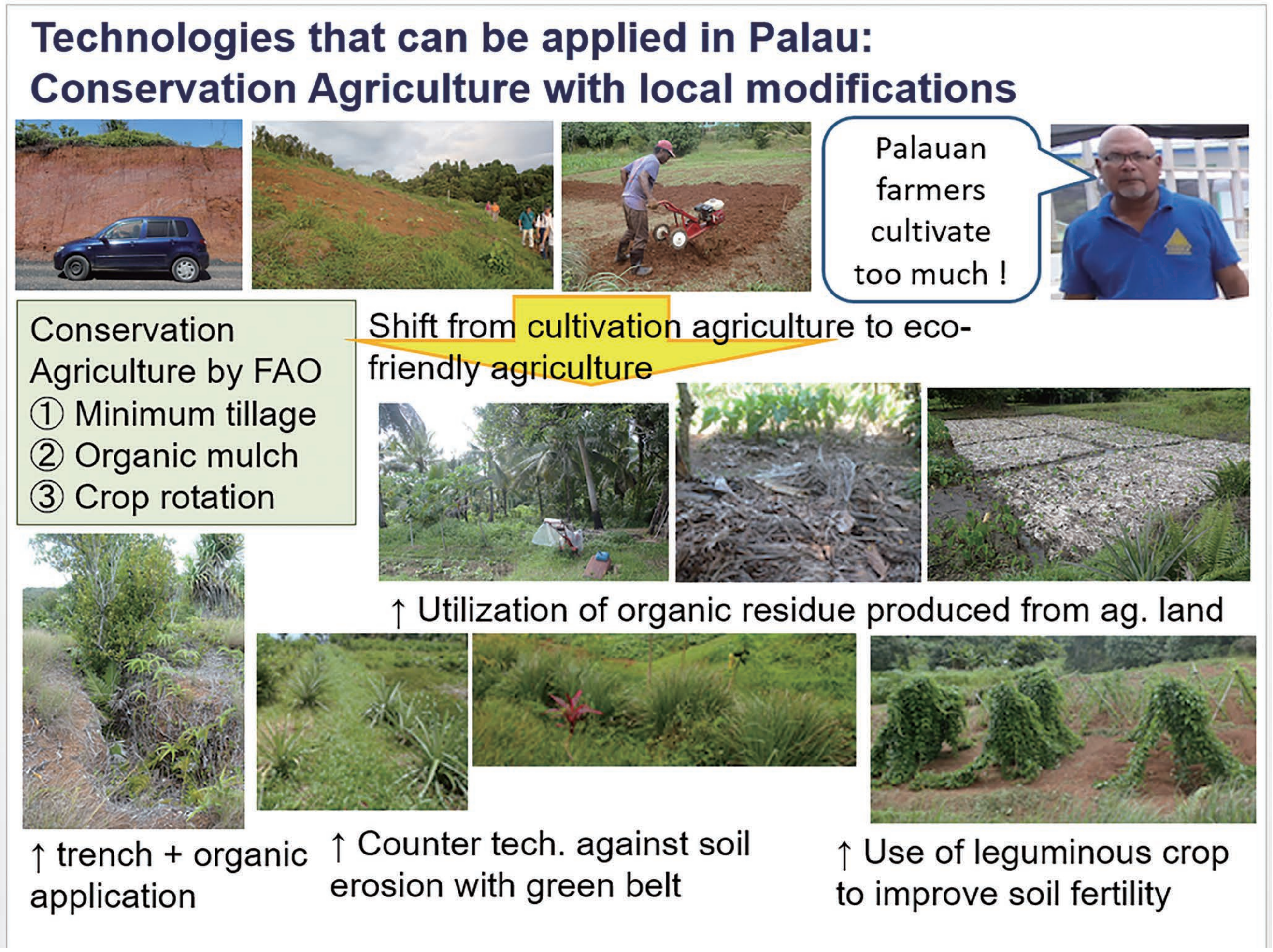

Fig. 44. Agricultural situation in Palau and possible solution

Research activities at Ishigaki, Okinawa, Japan, 2017-2018

To understand the effect of several types of minimum tillage (trench or handy auger) on soil erosion, water run-off, nitrate leaching and taro growth, we examined taro at artificial sloping fields (2, 3.5 and 5 degrees) of Ishigaki, subtropical islands of Japan for two years (Fig. 45). For easy collection and transportation of deposited soil in a sand basin, we used a fixation agent (Eeff-up; Nippon-Koei) to make over-saturated soil solid form (Fig. 46). By application of the sedimentation into the taro field, soil carbon and nitrogen content increased with 26%, crop biomass increased with 52% while soil erosion increased with 9% (Fig. 47 and 48). Soil erosion was supposed to have occurred by additional application of 6 t/ha of deposited soil on to crop fields and, thus, applied soil load may stimulate soil erosion compared to control (tillage without mulch) where no additional soil was added. Combination of no or minimum tillage (including drill and trench) + organic mulch increased taro biomass with 2-2.4 times in 2017 (Fig. 47), 2.8 times in 2018 (Fig. 48), and soil erosion decreased to only to 5-6% of the control in 2017, and 1-7% in 2018. We, thus, decided that this technology works very well and can be transferred to Palau for verification and for demonstration.

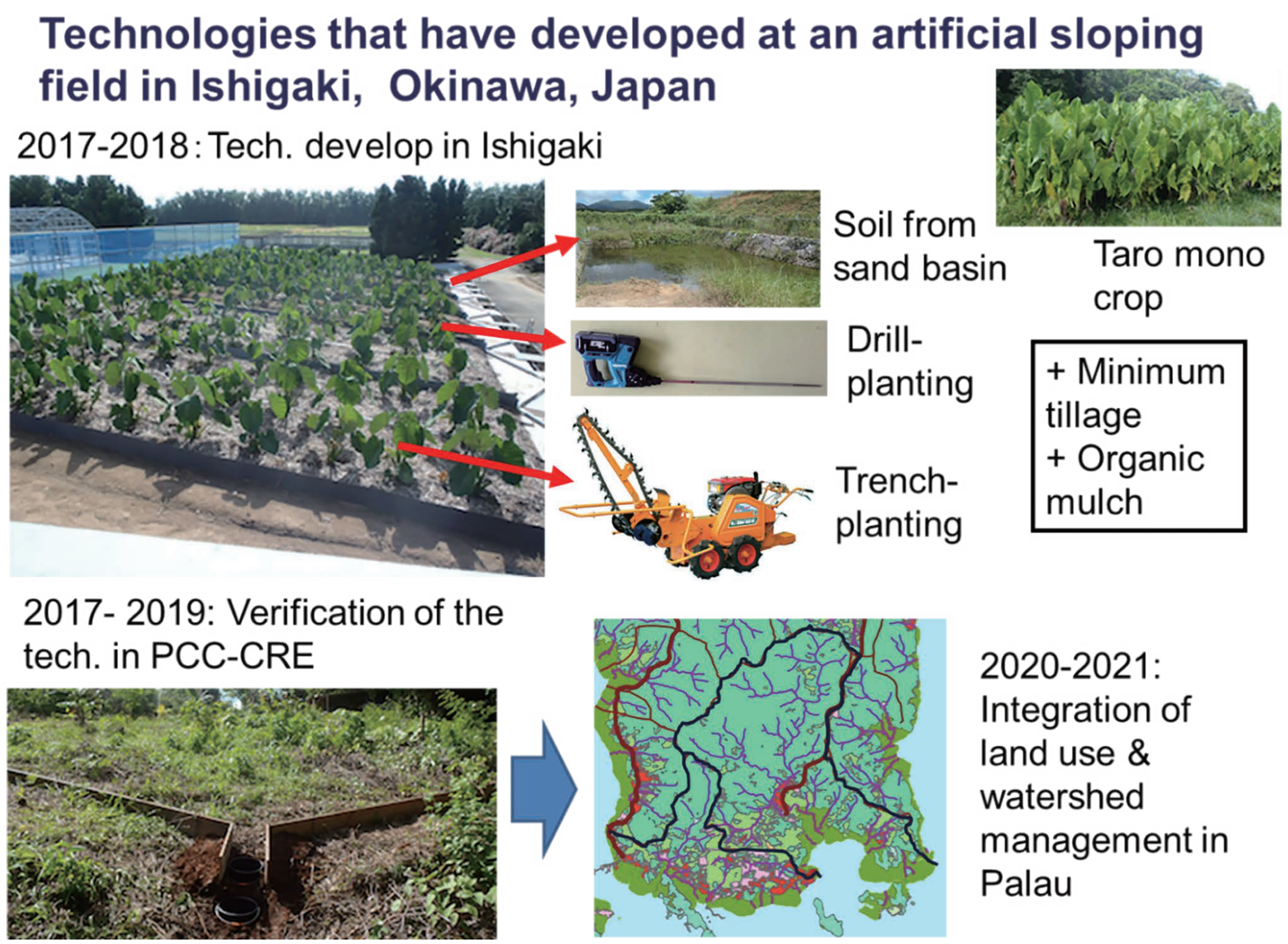

Fig. 45. Experiment on modified conservation agriculture in Ishigaki, japan and its verification to Palau.

Fig. 46. Application of deposited soil in sand basin for taro production in Ishigaki

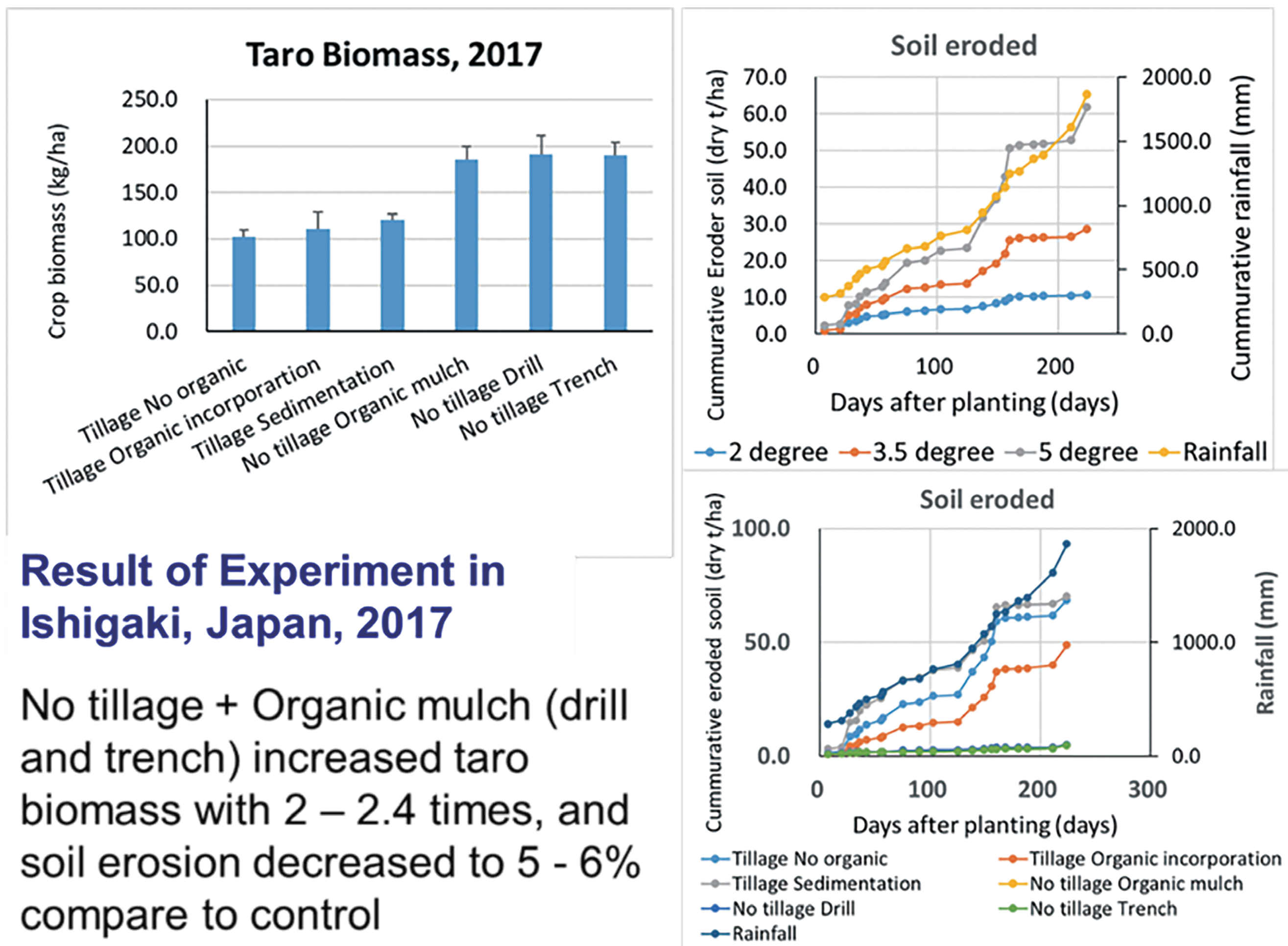

Fig. 47. Result of Experiment in Ishigaki, Japan, 2017.

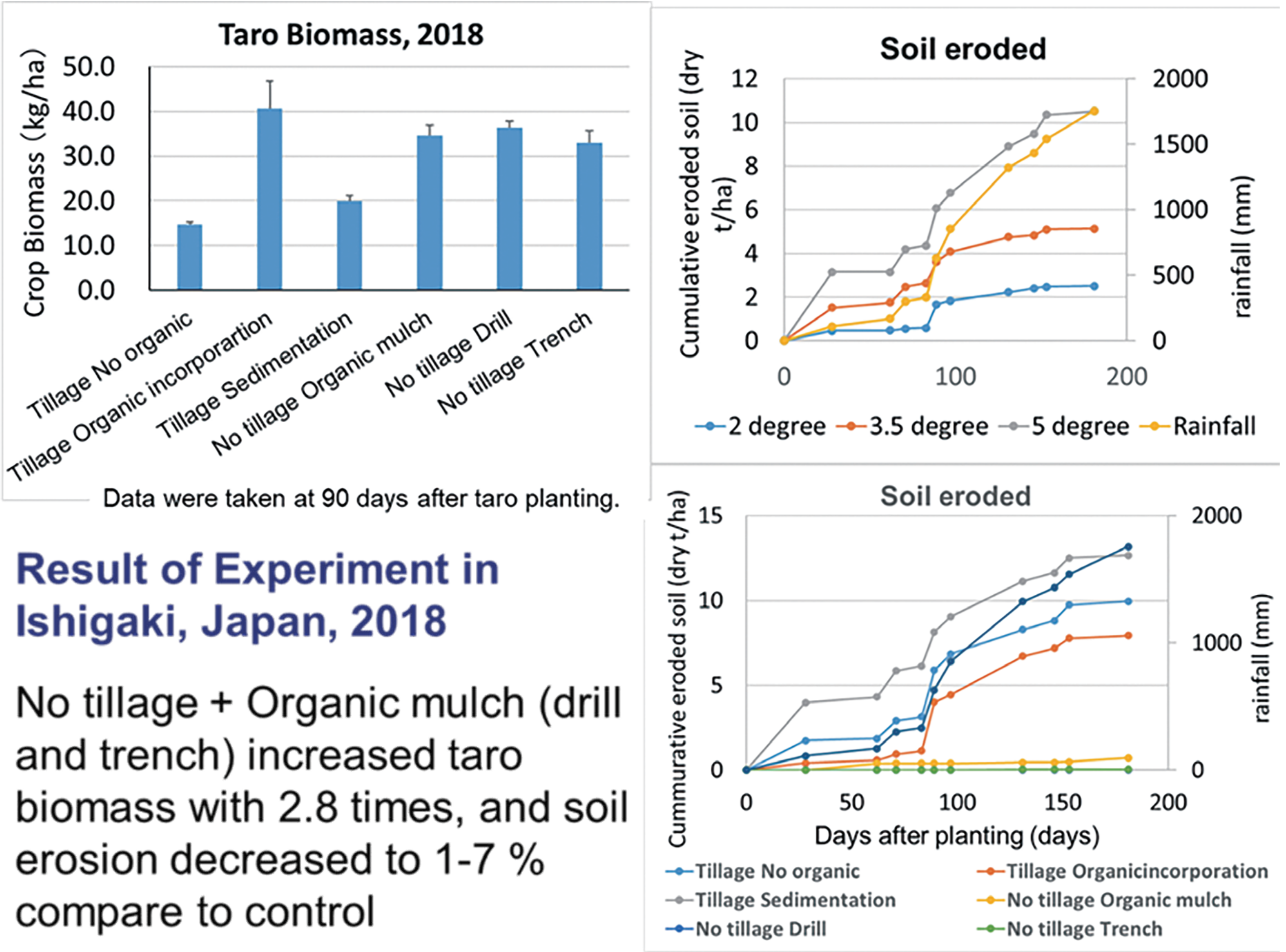

Fig. 48. Results of the experiment in Ishigaki, Japan, 2018

Research activities at PCC-Cooperative Research and Extension, Ngeremlengui, Palau

We have conducted fields experiments at Palau Community College, Cooperative Research and Extension (PCC-CRE) in Ngeremlengui, Palau to identify the effect of tillage methods on soil erosion of taro and sweet potato, and modified conservation agriculture on the biomass, yield and soil erosion in the upland root crop (Fig. 49). As modified conservation agriculture, we used a portable gas-powered auger and a trencher in the experiment, with the aim of improving soil fertility in the poor subsoil. We have conducted the experiments at the slope fields of PCC-CRE where the soil type is Babeldaob-Ngardmau-Udorthents with 11-30 % slope, which is categorized as “Soil amendment required for agriculture” as in Chapter 7. Studying the effects of slope and cropping design (taro contour farming and sweet potato patch-planting along the slope) on soil erosion revealed that the taro contour farming significantly decreased soil erosion. 16-19% slope increased soil erosion compared to the gentle slope (11-15%). Minimum tillage drastically decreased the soil erosion compared to tillage (Table 17). Next, the effects of tillage [minimum tillage with auger or trencher versus conventional tiller (control)] and mulching (no mulch versus yard long beans/sweet potato living mulch versus betel nut leaf mulch) on soil erosion and upland taro production was investigated. Taro corm yield was significantly higher in minimum tillage with organic mulch (auger and trencher with betel nut leaf mulch), versus the control (conventional tillage with handy tiller) as in Table 18. The highest significant average single corm weight was recorded from auger with betel nut leaf mulch. Eroded soil in minimum tillage was 5.1-11.3 times lower than that of the control (Table 19). Considering the increased yield and reduced soil erosion, minimum tillage using a handy auger with betel nut leaf mulch can be recommended as a proper practice for upland taro production in Palau.

The total rainfall during the crop growing periods in Ngeremlengui was 3,742mm; Seventy-one percent of the cropping periods were rainy, with rainfall over 20mm for 24% of the period (Fig. 50). According to the soil erosion study in Ishigaki, Okinawa, Japan, the soil in the artificial sloping fields (4 - 9%) had a risk of soil erosion when there was rainfall over 20mm per event. This data, thus, supported results showing high risk of water-induced soil erosion (Fraser et al., 1999; Mohamadi and Kavian, 2015) in Palau.

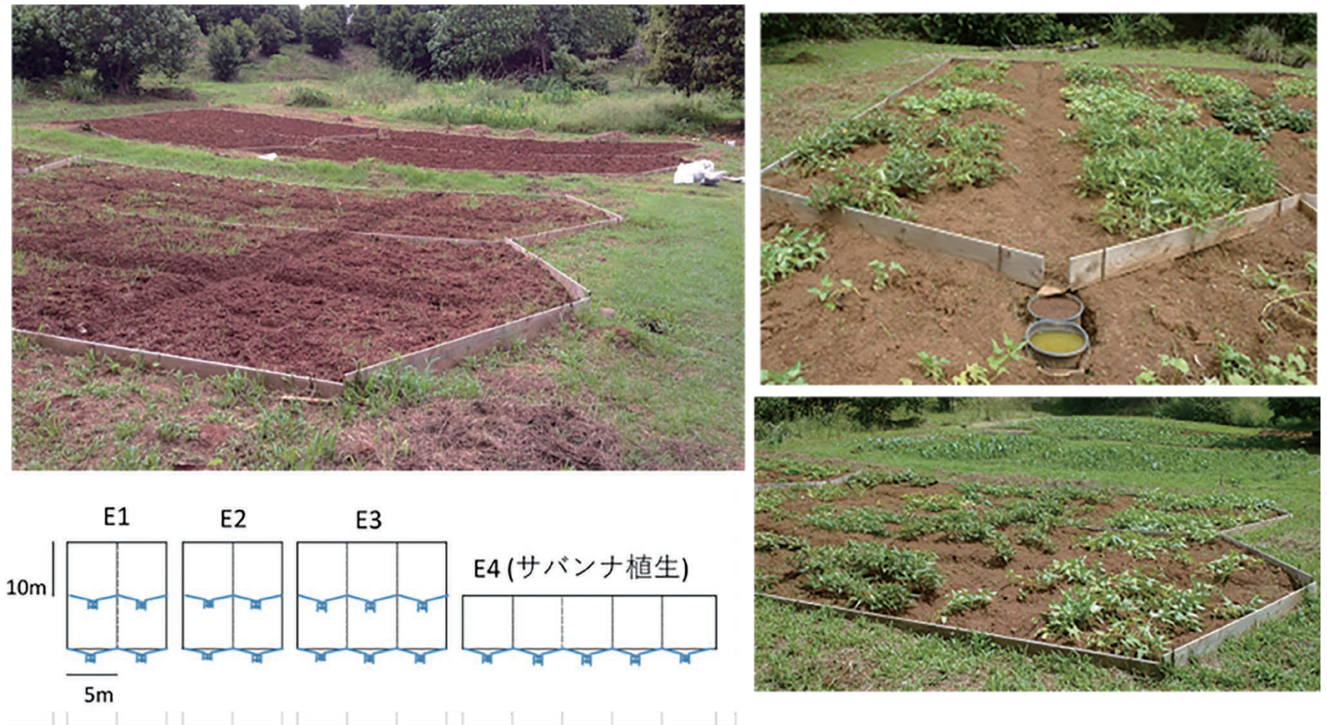

Fig. 49. Experiment on modified conservation agriculture in PCC-CRE, Palau
Left; Plot E1 from bottom to E3 to top, Right; Sweet potato planting on Square-shaped-bed at E1.

Table. 17. Effect of slope and crop+bed on soil erosion at PCC-CRE, Palau

Slope	Crop + Bed	Soil eroded (m^3/ha)
Medium	Sweet Potato planting on Square-shaped-bed	61.7
Low	Sweet Potato planting on Square-shaped-bed	19.8
Medium	Taro planting on horizontal ridge	43.1
Low	Taro planting on horizontal ridge	0.2
	Crop+Bed	0.017*
	Slope	0.008**
	Crop+Bed X Slope	0.11*

**Significant at P<0.01, *Significant at P<0.05. P values in the horizontal rows are the results of ANOVA. Low slope: 6.5-8.5, Medium slope: 9-11.0.

Table 18. Effect of tillage, planting and mulching on taro growth at PCC-CRE, Palau

Treatment	Biomass (dry t/ha)	Yield (dry t/ha)	Corm NO. (NO. /ha)	Mother corm (fresh g/corm)
Conventional tiller +no mulch	0.69	0.55	27,900	100.15
Conventional tiller +yardlong bean living mulch	1.26	1.04	46,000	148.85
Minimum tillage with trencher +sweet potato living mulch	1.10	0.94	38,400	147.65
Minimum tillage with auger +sweet potato living mulch	1.12	0.90	30,300	152.50
Minimum tillage with trencher +betel nut leaf mulch	2.04	1.76	79,700	178.85
Minimum tillage with auger +betel nut leaf mulch	2.33	1.96	55,700	256.35
ANOVA	0.065(n.s.)	0.038*	0.226(n.s.)	0.020*

*Significant at P<0.05, **Significant at P<0.01, n.s.=Non-significant. P values in the horizontal rows are the results of ANOVA and in the vertical columns are the results of Dunnett t-test for mean comparisons.

Table 19. Effect of tillage, planting and mulching on soil erosion at PCC-CRE, Palau

Treatment	Soil erosion (m^3/ha)	Slope gradient (°)
Conventional tiller +no mulch	35.00	12.25
Conventional tiller +yardlong bean living mulch	4.00	8.25
Minimum tillage with trencher +sweet potato living mulch	5.30	8.00
Minimum tillage with auger +sweet potato living mulch	5.10	8.75
Minimum tillage with trencher +betel nut leaf mulch	3.10	8.50
Minimum tillage with auger +betel nut leaf mulch	6.87	13.17
Dunnett t test	0.007**	0.51 (n.s.)

**Significant at P<0.01, n.s.=Non-significant. P values in the horizontal rows are the results of ANOVA and in the vertical columns are the results of Dunnett t-test for mean comparisons.

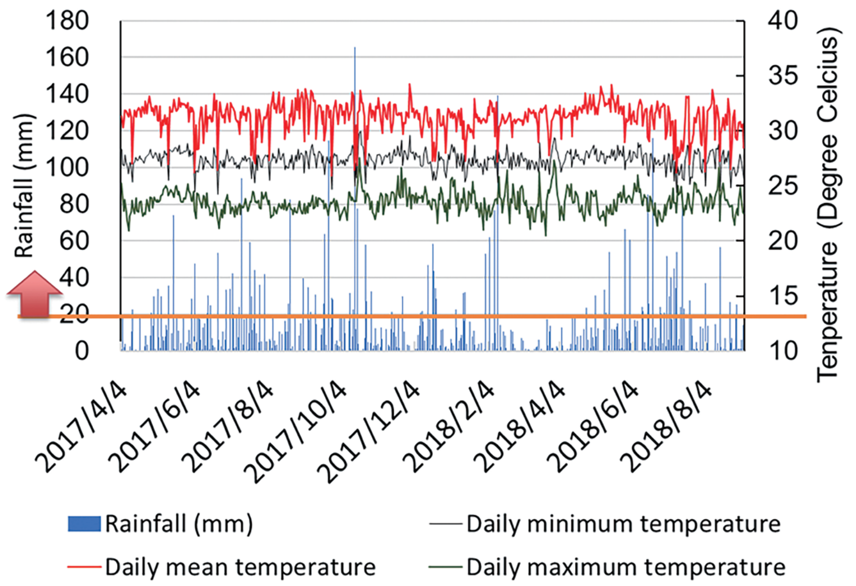

Fig. 50. Daily rainfall, mean, maximum, minimum temperature during crop growing period at PCC-CRE, Palau.

Participatory study for fruit tree production with minimum soil disturbance, Ngchesar, Palau

To see a possibility of tropical fruit production with the JIRCAS technologies where the soil type is Babeldaob-Ngardmau-Udorthents, we have opened a new field in the backyard of the BOA-Ngchesar in 2017. We introduced a trenching machine (NF-827LH Kawabe Co. Ltd., Tokyo, Japan) and a handy-auger (AGZ2600-EZ, Zenoah Co. Ltd., Saitama, Japan, Length x Width x Height; 2,150mm x 800mm x 1090mm) with drill (Diameter x length; 200mm x 930cm) to BOA-Ngchesar and had a small workshop about how to operate it (Fig. 51). The trenching machine can dig up to 1.0 m in depth and 20cm in width. The handy auger can dig a hole up to 0.9m in depth and 20cm in diameter by changing the drill.

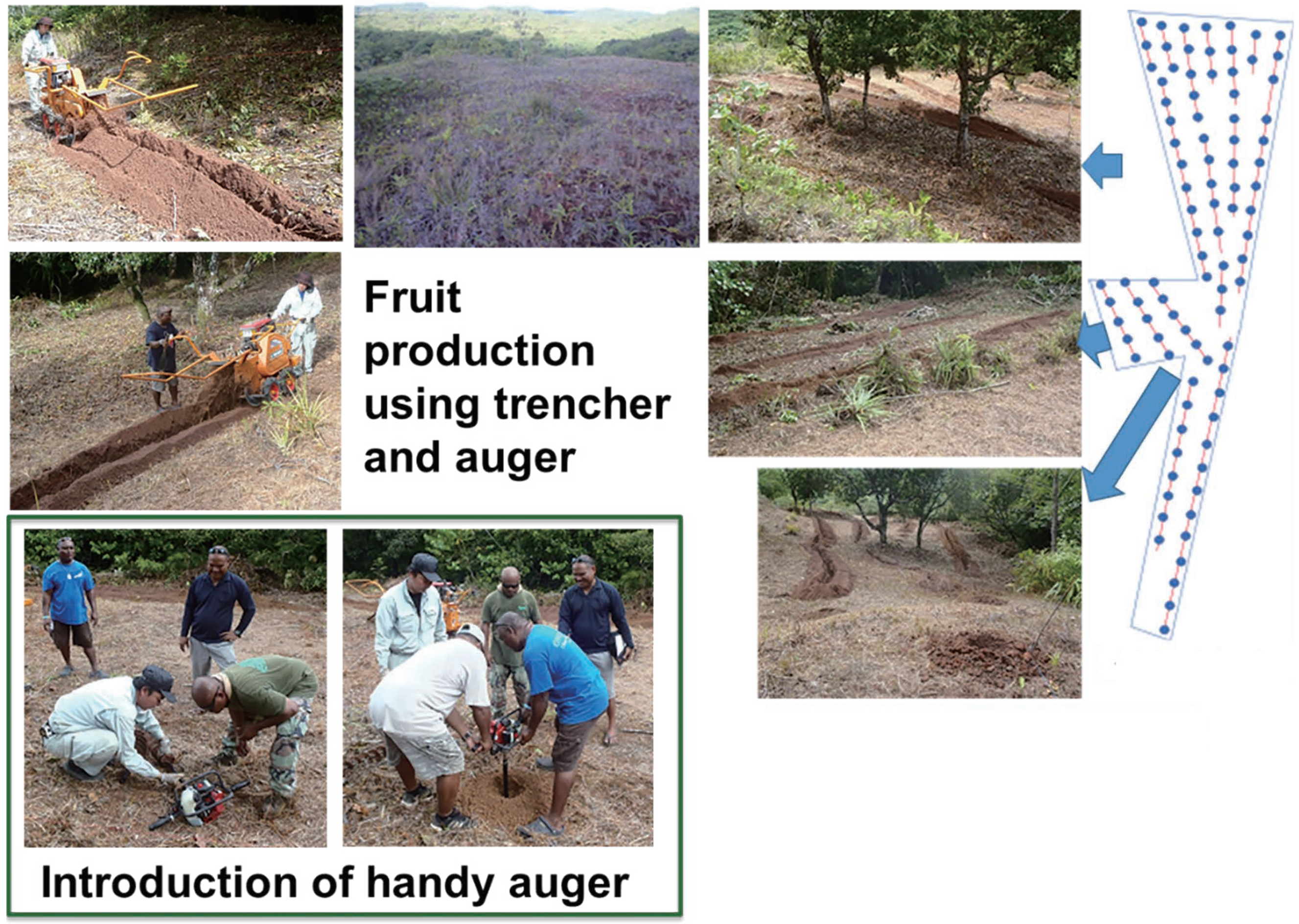

Fig. 51. Workshop for fruit production with trencher and handy-auger at BOA-Ngchesar, Palau.

After the workshop on the operation of the machines, we improved a tropical fruit garden at backyard of the BOA-Ngchesar with less than 30% slope where the soil type is Babelthuap-Ngardmau-Udorthents, categorized as “soil amendment required for agriculture” as in Chapter 7. We opened the garden with minimum soil disturbance (trenching machine and a handy-auger depend on the slope angle) and applied the organic materials such as sea sand for raising soil pH, compost for nutrients and trimmed twigs or leaves and so on into the excavated trenches or holes up to surface level (Fig. 52). We then planted several types of fruit seedlings and covered the surrounding ground with plastic mulch. (Fig. 53). After 2 to 3-years of management, we have conducted workshops on selection of fruit trees and varieties, propagation and pruning of fruit trees for sustainable tropical fruit production in Palau. The contents in the workshop were summarized in Chapter 9.

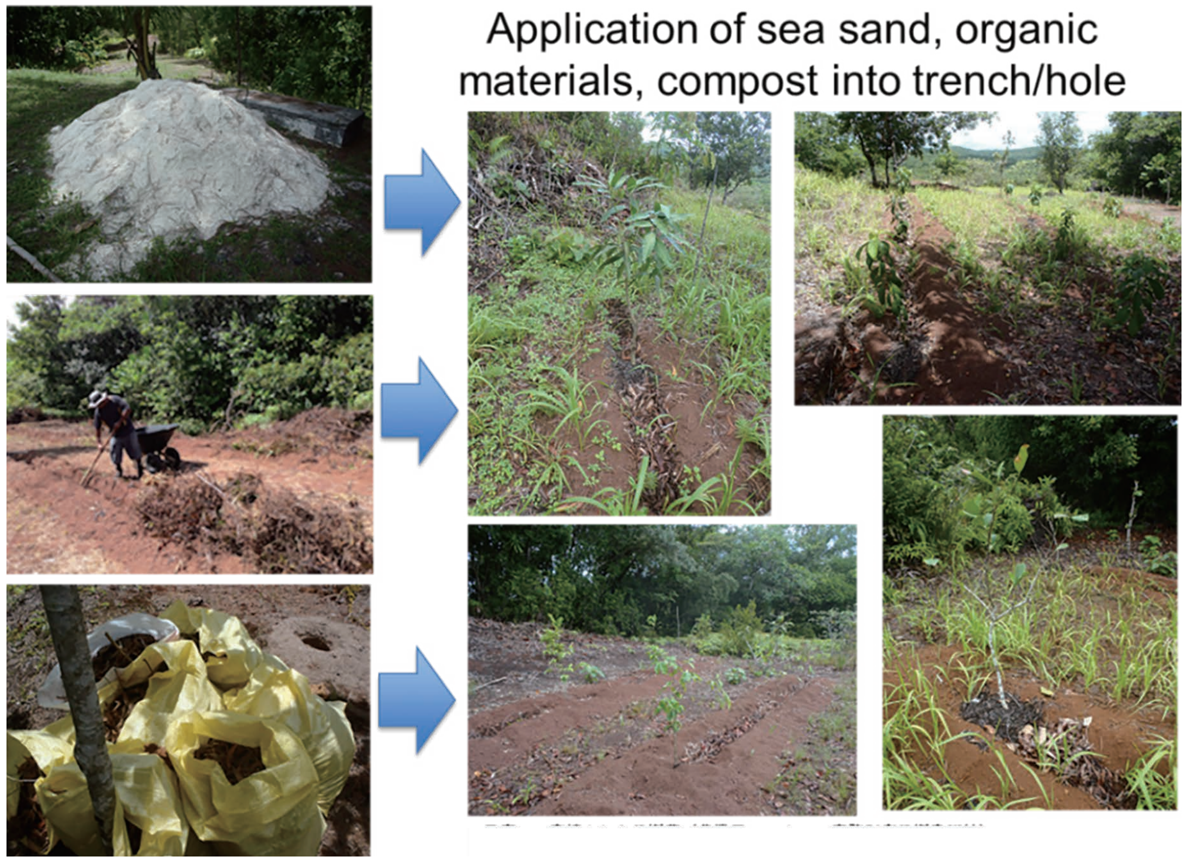

Fig. 52. Preparation for planting of tropical fruit seedlings at BOA-Ngchesar, Palau.

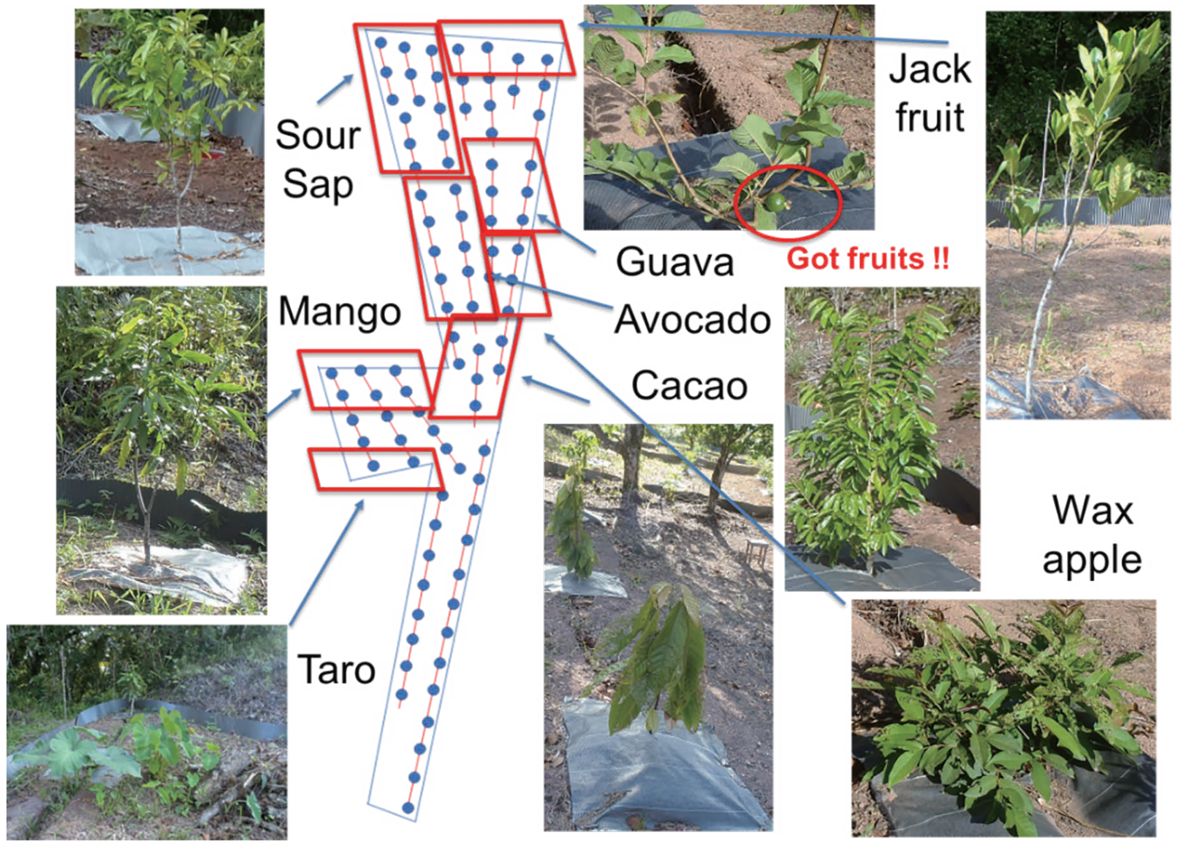

Fig. 53. Participatory study for tropical fruit production with modified conservation agriculture at BOA-Ngchesar, Palau.

Participatory study for taro production with modified conservation agriculture

For dissemination study of the technology of Conservation Agriculture (CA) with a handy auger, we called farmers who are interesting to practice to cultivating taro in combination of minimum tillage with a handy auger and organic mulch to see an advantage with conventional technology (taro seedling planting in bare and plowed fields) at another workshop in PCC-Assembly hall in 2019. This farmer's trials had continued for 6-7 months up to completing the taro harvest and the evaluation of the trials (Fig. 54). The local farmers who attended the trials enjoyed the technology and were aware of the combination advantage of the technology with a handy auger and organic mulch. For further dissemination trials, we made a poster for modified conservation agriculture (Fig. 55) and are promoting the technology.

Fig. 54. Participatory study for taro production with modified conservation agriculture.

Fig. 55. Promotion poster for participatory study on modified conservation agriculture.

Agricultural development of grassland in Babeldaob island with attention of traditional use

As mentioned in Agroforestry of Chapter 4, traditional structure and lifestyles still remain in villages of Babeldaob Island (Iida, 2011). Mulch agroforestry farms in combination with diverse agriculture and livestock are still active in several areas of the villages. A total of 36 useful wild plant species are routinely collected from the nearby agroforests and used by 60% of the villagers. Knowledge of medical plants and their uses have evolved over millenniums. Traditionally medical uses were secret knowledge to be closely guarded and passed through family lines (National review on the SDGs, 2019). Traditional Palauan knowledge about medicinal use of wild plants may help to secure the future of traditional plant-based medicine and thus prevent the disappearance of plants with therapeutic potential for Palau. If successful, this work will establish a health model for the Pacific and Palauans may once again become people that are so far from disgracing, live an ornament to human nature (Keate, 1789). In this aspect, we should carefully discuss and make an appropriate land design for agricultural development.

Glossary

Agroforestry: A multistory cropping system consisting of food-producing plants, such as bananas, breadfruit etc., mixed with trees that do not produce food.

Minimum tillage: Only the tillage essential to crop production and prevention of soil damage.

Organic matter: Plant and animal residue in the soil in various stages of decomposition.

Slope: The inclination of the land surface from the horizontal. One way to express slope is as a percentage. To calculate percent slope, divide the difference between the elevations of two points by the distance between them, then multiply the quotient by 100. The difference in elevation between points is called the rise. The distance between the points is called the run. Thus, percent slope equals (rise / run) x 100. Another way to express slope is as a slope angle, or degree of slope. If you visualize rise and run as sides of a right triangle, then the degree of slope is the angle opposite the rise. Since the degree of slope is equal to the tangent of the fraction rise/run, it can be calculated as the arctangent of rise/run.

Subsoil: Technically, the B horizon; roughly the part of solum below plow depth.

Swamp: An area of low, saturated ground. intermittently or permanently covered with water and vegetated dominantly by shrubs and trees, with or without the accumulation of peat.

Index of Genera and Species

Scientific	Common	Palauan
Areca catechu L.	betel nut Palm	buuch
Colocasia esculenta (L.) Schott	taro	dait, kukau
.*Ipomea batatas* (L.) Lam	sweet potato	emu tii
Vigna unguiculata L. Walp. *subsp-sesquipedalis (L.) Verdc.*	yard long bean	

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CHAPTER 11

SOIL AMENDMENTS FOR INCREASED AGRICULTURAL OUTPUT

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Introduction

As highlighted in earlier chapters, the geology, landscape, and soils of Palau are very diverse and varied, with soil scientists identifying over 32 major soil types (NRCS, Soil Survey). Due to this reason, and a confluence of other factors, agricultural production in Palau is faced with a variety of challenges. The prevalence of steep slopes (60% of soil types have slopes of 30% or more), weathered and erodible soils, high aluminum saturation, and soil acidity further exacerbate this situation. In addition, “Palau is highly vulnerable to sea level rise and on-going climate extremes due to El Niño– Southern Oscillation (ENSO) events” with “the frequency and intensity of extreme climatic events (particularly extreme high tides) expected to increase under the pressures of climate change.” (Taro, PACC Food Security Project).While historically, traditional agriculture and fishing supported a large population, Palau currently imports almost 85 % of food products consumed. In 2010, this cost over $24.5 million and accounted for 10 percent of total GDP. Though these factors pose considerable environmental, economic, and food security challenges, there are practical solutions that can be utilized in order to overcome these challenges and achieve increased agricultural output in Palau.

The creation, commercialization, and wide-spread application of low-cost, locally-produced soil amendments represents one of these solutions. When paired with soil testing and