CHAPTER 6
CONSTRAINTS FOR AGRICULTURE DEVELOPMENT

Fredrick Ikertang and Hide Omae

With any ecosystem there are factors that may reduce productivity of crop productivity. In this chapter we discuss these factors and throughout the text methods for overcoming these constraints are described in the context of increasing agriculture success rate.

Slope steepness

As mentioned in Chapter 3, Palau is geologically complex. It includes a mixture of older and volcanic and metamorphic substrates on the large island of Babeldaob (20-40 million years before), limestone parent material capping volcanic core material on smaller islands to the south, and hundreds of small islands farther south. Palau's largest island, Babeldaob, has the most available land for agricultural production. The land, however, has a small flat and a larger part is occupied by slopes. We, thus, should consider the steepness of the slopes, at first, for agriculture production in Palau. Where slope is gentle slopes (~ ca. 12%), we can use any type of machines to plow and, thus, we can plant all crops with ordinal care like natural terracing (Perry, 1987). Farming on steeper slopes (~ ca. 30%), where only a small handy tiller can work, drastically increases the risk of soil erosion. We, that's why, do not recommend agricultural production without taking appropriate countermeasures against soil erosion. Very steeper slopes (more than 30%) can be partially used for fruit production in the other countries (e.g. mandarin production in mountainous areas of Japan). We, however, do not recommend it at present because of high risk of accidents without any infrastructures (e.g. hillside ditches, green belt, construction of artificial terrace, work road, and railway for products carrier). Use of sloping land less than 30% should be considered by assistance of the national or state government at first without high cost of infrastructure.

Soil fertility

Most of the upland soils in Babeldaob Island are oxisols. Oxisols are old highly weathered soils that are extremely infertile, and the reservation of plant nutrients is not good. The soils are limited to a very low cation-exchange capacity and very few weatherable minerals. The soil is acidic, high contents of soluble aluminum and has very little soil organic matter. The major challenges for these soil types are increasing and maintaining the soil fertility level. From these situations, soil organic matter (SOM) plays very important roles for soil fertility (See Chapter 3). Agricultural development, thus, could be evaluated whether the SOM rich layer reaches enough to the efficient soil depth for crop root development or not. Mesei-Dechel-Ngersuul soils categorized as soils of bottom lands were formed in alluvial sediments or organic materials. This thick surface layer (the depth of SOM above 1% by weight is 51-200cm) has low toxic to aluminum (Aluminum saturation is 0-11%), optimum pH range for crop growth (pH 5.5-6.0), and sufficient nutrients (CEC is 48-161%, ECEC is 37-121%), thus, has been used for wetland taro production for long time (Table 6). Aimeliik-Palau-Ollei soil group categorized as soils on volcanic uplands have thick surface layers that have deep depth of organic matter (the depth of SOM above 1% is 38-94cm), relatively low aluminum saturation (0-39%), optimum pH range for crop growth (pH 5.8-6.5), and sufficient nutrients (CEC is 26-115%, ECEC is 10-95%). Aimeliik soils are more fertile than Palau soils and the other soils on volcanic uplands and support more vegetation such as mixed-upland forest. Babelthuap-Ngardmau-Udorthents, categorized soils on volcanic uplands, by contrast, have very thin and low concentration of organic matter (the depth of SOM above 1% is 2-5cm), high aluminum saturation (61-70 %), relatively low pH for crop growth (pH 5.5-5.6), and low nutrients (CEC is 19%, ECEC is 7%). About 70-80% of the surface is covered by gravel. Because of these reasons, agriculture production in this category is very difficult and requires soil amendment especially in the subsoil layer to get sufficient root growth.

Table 6. Soil properties at the surface soil from 0-3cm

USDA Soil map Unit	Soil depth (cm)	Al. sat. (%)	Soil pH	Bulk density	CEC (%)	ECEC (%)
Mesei-Dechel-Ngesuul	51-200	0-11	5.5-6.0	0.1-0.4	48-161	37-121
Odesangel	45	0	8.6	0.1	160	80
Ilachetomel-Naniak-Chia	84-121	0-3	5.0-8.4	0.4-0.6	75-88	64-79
Tabecheding-Ngatpang-Dysrudepts	13-126	1	5.0-5.5	0.7-0.8	50	45
Aimeliik-Palau-Ollei	38-94	0-39	5.8-6.5	0.1-0.8	26-115	10-95
Babelthuap-Ngardmau-Udorthents	2-5	61-70	5.5-5.6	0.4-0.9	19	7
Peleliu Chelbacheb	24-30	0	9.2	0.1	150	149
Ngedebus-Majuro	14	-	8.6	0.1	95	-

*The data was partially extracted and summarized per each USDA soil map unit from the original source (USDA-NRCCS, 2009, 2019; Iida, 2012).

When we compare the soil properties in the subsoil layer where the SOM decreased below 1% at Babeldaob island (Table7), we can observe a typical weathered soil character derived from volcanic rock except for Odesangel and Ilachetomel-Naniak-Chia. The soil pH is low (2.3-4.9), three phase soil distribution is rich in silt and clay (6-20% for soil, 20-65% for silt and 15-60% for clay), specific gravity is relatively light (bulk density is 0.7-1.4). Soil nutrition is poor (CEC is 5-25%, ECEC is 2-11%). Aluminum solubility in soil, on the contrast, is high (Aluminum saturation is 28-95%). As mention the influence of low pH in Chapter 3, availability of many nutrients such as P, K, Ca, Mg tends to be low under acidic soil (pH<5). Soluble aluminum has toxicity for plant growth. High soil aluminum causes root damage (Fig. 17 in Chapter 3). Although silt and clay rich soil has a strong holding capacity for nutrition, the soil is easy to form hard-pan and, thus, crop root is not easy to penetrate through the hard-pan and moisture damage can often happen. Those problems are more obvious when the organic-rich soil layer is narrower than root growth depth since the organic has a function to weaken the problems as mentioned in Chapter 3.

Water availability and management

Water significantly affects crop production. Soils of Dechel, Mesei, Ngerungor, and Odesangel are wet throughout the year and thus, there is less problem on water supply to the crop. Those soils have been traditionally used for wetland taro. Water management in upland soil, on the contrary, is more important than in the bottom land. Supplemental irrigation may be required during the dry season. The amount and timing of irrigation depend on the needs of the crop and water holding capacity of the soil. Some soils such as the sandy Ngedebus soils, have a high permeability rate and a low water holding capacity. The water, thus, does not stay long in the soils. Silt or clay rich Soils such as Palauan soils have a higher water-holding capacity, and can be managed with less frequent irrigation.

Table 7. Soil properties at the subsoil, where organic matter decreased to 1%

USDA Soil map Unit	Al. sat. (%)	Soil pH	Bulk density	CEC (%)	ECEC (%)
Mesei-Dechel-Ngesuul	28-39	3.8-4.5	1.0-1.1	18-25	10-11
Odesangel	-	3.0	1.7	0	70
Ilachetomel-Naniak-Chia	34	3.2-6.8	0.7-1.4	0-43	50-55
Tabecheding-Ngatpang-Dysrudepts	91-95	2.3-3.6	1.0-1.4	5-18	2-3
Aimeliik-Palau-Ollei	44-93	4.5-4.9	1.1	12-24	4-10
Babelthuap-Ngardmau-Udorthents	93	4.7-4.8	0.7-1.2	7	2
Peleliu Chelbacheb	-	5.4	0.7-1.1	50-88	120
Ngedebus-Majuro	-	7.0	1.7	0	-

*The data was partially extracted and summarized per each USDA soil map unit from the original source (USDA-NRCCS, 2009, 2019; Iida, 2012).

Glossary

Aluminum saturation: The amount of KCl-extractable Al divided by extractable bases (extracted by ammonium acetate) plus the KCl-extractable Al. It is expressed as a percent. A general rule of thumb is that if there is more that 50 percent Al saturation, Al problems in the soil are likely. The problems may not be related to Al toxicity but to deficiency of calcium and/or magnesium

Cation exchange capacity: The total amount of exchangeable cations that can be held by the soil, expressed in terms of milliequivalents per 100 grams of soil at neutrality (pH 7.0). or at some other stated pH value. The term, as applied to soils, is synonymous with base-exchange capacity but is more precise in meaning

Gravel: Rounded and angular fragments of rocks as much as 3 inches. (2 millimeters to 7.6 centimeters) in diameter. An individual piece is pebble

Hardpan: A hardened or cemented soil horizon, or layer. The soil material is sandy, loamy or clayey and is cemented by iron oxide, silica, calcium carbonate, or other substance

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 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

References

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