Glossary

Bauxite: A residual rock-weathering product consisting of hydrated aluminum oxides; the principal commercial source of aluminum

Bottom land: The normal flood plain of a stream, subject to flooding

Fluviomarine terraces: Constructional coastal strip, sloping gently seaward and /or down valley, veneered or completely composed unconsolidated sediments(typically clay silt, sand and fine gravel). Sediments were deposited by both marine and fluvial processes, resulting from sea level fluctuations and/or stream migration

Marine terrace: See Fluviomarine terrace

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CHAPTER 8

TECHNICAL PERSPECTIVE FOR FUTURE CROP PRODUCTION

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Soil Amendments for increased agricultural output

Before you begin farming, it is very important to get your soil tested to determine the soil type and condition. When farming in poor quality soil, you can do one or both of the following. First, you can garden using native plants and plants already adapted to your soil. Or, you can amend the soil for the type of plants you wish to grow. A soil amendment is any material, organic or inorganic, added to a soil to improve its physical and/or chemical properties, such as drainage, water retention, aeration, permeability, water infiltration and/or pH, CEC and other soil properties.. This in turn improves biological properties of the soil. The main goal for adding amendments is to improve the soil structure and chemical properties thus improving the root environment for plants. Knowing and understanding the characteristics of your soil type can help determine the amount and type of amendment to add to your soil to improve its structure. Table 13 shows that both sandy soils and clayey soils are the most challenging soil types for farmers from the viewpoint of soil physical properties. Whereas loamy soils have the ideal mixture for better crop growth due to better structure. Soil structure is one of the key properties affecting the productivity of soils and the environmental side effects of agricultural soils (Soinne et. al, 2014). For a soil amendment to work properly, it must be thoroughly incorporated or mixed well into the soil. To just bury the amendment will reduce its effectiveness and will interfere with water and air movement and root growth (Davis and Wilson, 2005).

Table 13. Permeability and water retention of various soil types.

Soil Texture	Permeability	Water Retention
Sand	High	Low
Loam	Medium	Medium
Silt	Low	High
Clay	Low	High

Source: Davis and Wilson. 2005. Colorado State University Extension.

Organic amendments come from something that was once alive while inorganic amendments are either mined or man-made. Choosing the right amendment is determined by the soil type and the plant type to be grown in the farm. Adding organic amendments will increase soil organic matter (SOM) which offer many benefits including improved water and nutrient holding capacity, mitigation of Al toxicity. Many organic amendments contain plant nutrients and act as slow release fertilizers. Organic matter also is an important energy source for microbes and earthworms that live in the soil.

There are four (4) factors to consider when selecting a soil amendment: 1) how long the amendment will last in the soil, 2) what is the soil texture, 3) the soil salinity and plant sensitivities to salts, and 4) the salt content and pH of the amendment (Davis and Wilson, 2005). It is very important to have your soil tested to determine salt content, pH, and organic matter contents of organic amendments. Table 14 shows the decomposition rate of different types of organic amendments.

Table 14. Decomposition rate of various amendments.

Amendment	Decomposition rate
Grass clippings, manures	Rapid decomposition (days to weeks)
Composts	Moderate decomposition (about 6 months)
Wood chips, hard bark, peat	Slow decomposition (possibly years)

Source: Davis and Wilson. 2005. Colorado State University Extension.

The goal when amending sandy soils is to increase the soil's ability to hold moisture and store nutrients. Well decomposed organic amendments can be used to achieve this goal. These amendments include, composted leaf litter, composted garden and grass clippings, well-aged manures, or a combination of all following the proper composting procedures. Composted organic materials have a positive effect on soil physical properties and soil structural stability (Tejada et al, 2009). Regular addition of composted organic materials will increase soil physical fertility by improving aggregate stability and decreasing soil bulk density (Diacono and Montemurro, 2011). Another positive role organic amendments play is in climate change mitigation by soil carbon sequestration.

With amending clay soils, the goal is to improve soil aggregation (flocculation), increase porosity and permeability, and improve aeration and drainage. Organic amendments to achieve this goal include fibrous amendments such as peat, wood chips, tree barks, or straw. Biochar can also be used to amend clay soils. Biochar increases aggregate stability and reduces the detachment of colloidal material thus reducing surface erosion (Soinne, 2014). This in turn aids in the reduction of surface particulate phosphorus loss from agricultural fields (Soinne, 2014).

Seagrasses can also be composted or added to a compost pile and used as a soil amendment. Seagrasses are nutrient rich, they help preserve soil humidity, and contain calcareous epiphytes on them that help stabilize soil pH by acting as buffers (Lucca-Broco, 1984).

Lime and coral sand are another amendment that improve soil acidity and Al toxicity in Palau' soil. Calcium carbonate (CaCO3) in them works to increase soil pH and decrease exchangeable Al concentration.

Gypsum is another amendment that has the potential to slow down phosphorus loss particularly in agricultural areas with high phosphorus loss potential (Uusitalo et al, 2012). Gypsum is mainly used as a calcium source for legumes and as a soil conditioner on sodic soils (Shainberg et al, 1989).

Erosion control

Adaption of counter technology against soil erosion is very important especially in Palau where many lands are occupied by the slopes. Soil erosion greatly reduces the suitability of the most soils for crop production. If possible, crop cultivation with tillage practice should be conducted on gentle slopes. If the steeper slopes must be cultivated, several measures should be taken to reduce the risk of erosion. Contour farming is recommended on all sloped fields. Where the slope is 7-12%, natural terracing is a good practice with ordinal care of plants plaiting on a contour (Perry, 1988). In case below 25% slope , hillside ditches are an appropriate practice. Farming on slopes greater than 10%, however, make soil erosion control more difficult. Use of mulch cover, no till or minimum till planting should be considered as a next step for minimal soil disturbance. The most efficient way to reduce the risk of erosion is to keep the soil covered with living plants or mulch. Mulch protects the soil from the impact of raindrops. It reduces compaction from heavy rains, increases the water filtration, and therefore, decreases the runoff rate and hazard of erosion. Mulch also conserves soil moisture, suppresses the weeds growth and maintains a soil temperature, Mulch includes any type of organic materials (e.g., grasses, tree leaves, coconut fronds) that is applied to the ground around the plants. Organic mulch improves the soil fertility when it decomposes and is mineralized. Application of organic matter with certain thickness (3 to 4 inches) actually builds topsoil. The more topsoil we have the more it can supply the nutrients necessary for the plant growth.

Soil chemistry

Soil acidity are important factors to influence soil fertility on volcanic uplands and marine terraces. Soil pH is an expression of soil acidity. The soil pH is considered a master variable in soils as it affects many chemical processes as mentioned in Chapter 1. It specifically affects plant nutrient availability by controlling the chemical forms of the different nutrients and influencing the chemical reactions they undergo. The optimum pH range for most plants is between 5.5 and 7.5. In strongly acidic soils below pH 5, availability of many nutrients including P, K, Ca, Mg tends to be low (Fig. 15). In extremely acidic soil below pH 4.5, aluminum solubility becomes high (Fig. 16). Soluble aluminum in soil has toxicity for plant growth. High soil aluminum causes root damage (Fig. 17). Some plants, including Chinese cabbage and tomatoes, are highly sensitive to the acid soils. Other plants such as cassava, yams, pineapple, sweet potatoes, sugarcane, noni, and black pepper are less sensitive to aluminum in the soils. Applications of lime is a standard measure to reclaim the soil acidity. Commercial lime like Dolomite is made of pure, imported limestone that can reduce acidity. Dolomite is available in Palau, contains a large amount of magnesium and calcium and, therefore, useful for raising the soil pH and for plant growth. Crushed coral and coral sand are locally available forms instead of commercial lime. Palau is fortunate to have a vast supply of lime in the form of coralline sand and limestone. However, it usually takes time to see the positive effects of these materials as they dissolve very slowly over time. Therefore, we should grind the coral and/or sand to the finest grain size possible so as to improve their effectiveness (Smith and Babik, 1988).

Organic matter application

Increasing the content of organic matter through mulching and other means also decreases the negative effects of soil acidity on crop production. Soil organic matter (SOM) promotes a healthy soil environment for beneficial organisms as in Chapter 3. SOM allows the soil to hold on to and recycle nutrients i. e. SOM acts as a slow-release fertilizer so nutrients do not leach out of the soil too fast. SOM improves soil aggregation and structure that contributes to better permeability and leads to lower erosion. SOM improves water holding capacity. SOM binds aluminum so that it detoxifies soluble aluminum in soil. Organic fertilizer, therefore, can be used to restore and potentially increase the soil fertility such as animal manure, fish meal and compost. In general, a ratio of 1-part nitrogen-rich materials to 3 parts carbon-rich materials is recommendable for making compost. Tillage, especially mechanized tillage, can quickly decrease the content of organic matter in tropical soils. In addition, when soil is eroded, topsoil (where nearly all the soil fertility resides) is lost more quickly compared to the subsoil. We, thus, should manage very carefully to minimize the loss of topsoil and organic matter for crop production. Using adequate amounts of mulch and/or compost and returning all crop residue to the soil after harvest are the simplest way to maintain the content of organic matter in cropped areas.

Legume fallow

Sanjay (2016) studied the efficacy of fallow experiments of four cover crops namely grass, Mucuna spp., Erythrina spp. and biochar over four agro-ecological zones in Samoa. The fallow treatments significantly improved the soil active carbon stocks upon decomposition. Mucuna fallow contributed to the largest additions of biomass across all the agro-ecological sites and proved that Mucuna sp. is a superior cover crop with improving soil active carbon, soil biological activities.

Conservation agriculture

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 soil erosion (Hobbs, 2007; Hobbs, et al., 2008; Reicosky & Saxton, 2007). Conservation agriculture is widely disseminated with some modifications depending on regional situation and farmer's adoptability. 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, Babeldaob island, the largest volcanic island in Palau, is composed of basalt and andesite. Infertile poor organic matter containing very acidic red iron and aluminum-rich oxisols is the dominant in subsoil of the steep upland; making 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, and can be a viable option to introduce conservation agriculture in the steep upland, too. Amendment of sub-soil by use of a mechanical handy driller or trencher also might be other options to minimize soil disturbance, support shortage of young hard-worker, and to promote crop root development to increase the yield in order to realize conservation agriculture in Palau.

Agroforestry

There is a long history for Palauan to adapt agroforestry systems, including the more permanent and stabilized systems of 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 and maximum organic matter input for countermeasure against soil erosion. This method involves planting of multi-fruit trees, medicinal plants or shrubs, and food crops intermixed or in small patches. All areas are maintained by covered with plants or organic mulch. Mulch needs to be maintained regularly since it will be ordinarily decomposed within 3-6 months. In agroforestry systems, several crops such as upland taro, breadfruit, bananas, papaya, noni and wood crops can be grown. Agroforestry systems also can provide commercial products for sale such as wood for woodcarving, fruit, herbs, vegetables and medical plants.

Glossary

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

Permeability: The quality of the soil that enables water or air to move downward through the profile

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

Topsoil: The upper part of the soil, which is the most favorable material for plant growth. It is ordinally rich in organic matter and is used to top dress road banks, lawns, and land affected by mines

Index of Genera and Species

Scientific	Common	Palauan
Erythrina		
Mucuna pruriens	velvet bean	

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