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Experiment of "no-tillage" farming system on the volcanic soils of tropical islands of Micronesia

Mohammad H. Golabi[1], S. A. El-Swaify[2], and Clancy Iyekar[3]

Abstract

The soils of southern Guam are formed from very deep; well-drained Saprolite derived from volcanic based tuff and tuff breccias. These soils suffer severe erosion as the result of rapid overland flow, wind and intensive rain events typical of southern Guam. An integrated approach to control the accelerated soil erosion was designed to include conservation tillage, crop rotation with leguminous plant, and residue management for soil surface cover.

The objectives of this study are; 1) to evaluate the use of crop rotation and tillage management for increasing organic-matter content to improve the overall quality of these severely eroded soils, 2) to evaluate the effect of conservation practices on harvested yield and crop productivity of these eroded soils and, 3) to assess the effects of conservation techniques including no-tillage systems on water runoff and infiltration. This paper discusses the effect of conservation strategies and techniques on these severely eroded soils of southern Guam.

Key Words: Conservation agriculture, No-Tillage system, Volcanic soils, Micronesia, Guam

1 Introduction

Accelerated soil erosion, often as a consequence of poor soil quality, degrades the soil resource and degrades the downstream environment in Guam. These threats are manifested most seriously in the southern part of the island. The challenge facing soil and agricultural scientists is, therefore, to develop soil conservation strategies that restore the health and resilience of the soil, and improve soil quality for crop production and maintain the integrity of the environment.

This research, therefore, evaluates the effectiveness of certain conservation techniques in controlling runoff and reducing soil erosion on these highly degraded volcanic soils of southern Guam. These include soil management systems such as conservation tillage (no-tillage and reduced-tillage), and crop rotations with leguminous sunn hemp (*Crotalaria juncea*) with maize (*Zea mays*). These techniques are intended to maintain surface cover before the subsequent cultivation of the main crop (maize). The sunn hemp also serves as green manure to improve the quality of the soils due to its high organic matter content upon its incorporation to the soil.

Plant cover intercepts and dissipates the energy of raindrops before they strike the soil, enabling the water to infiltrate the soil surface and prevent over flow. Furthermore, the resulting buildup of plant stems, roots, and organic matter act to improve soil quality (El-Swaify et al., 1988) hence makes the soil more resistant to erosion. Although many soil-conservation technologies can be combined to reduce erosion rates, reduced-tillage can play a key role in reducing soil erosion, decreasing weed pressure through maintenance of surface mulch, and enhancing soil productivity through crop residue and organic-matter maintenance. The principal method of controlling rapid surface runoff and the resulting soil erosion is to maintain adequate vegetative and/or crop residue cover on the soil surface at all times. The greater water infiltration and reduced evaporation afforded by

[1] Professor of Soil Sciences, College of Natural and Applied Sciences, University of Guam. Corresponding author: E-mail: mgolabi@uguam.uog.edu

[2] Emeritus Professor of Soil Sciences, Division of Soil, College of Agriculture, University of Hawaii

[3] Research Associate, College of Natural and Applied Sciences, University of Guam

crop residue results in more water available for crop use under such management (Hargrove, 1985; NeSmith et al., 1987).

One of the immediate benefits of conservation tillage is the increased population of earthworms (Golabi et al., 1995). The passageways dug by earthworms allow plant roots to penetrate deeper into untilled soil than they do into conventionally plowed soils (De Quattro, 1997). Golabi et al., (1995) have reported that earthworm passageways also increase water infiltration and consequently moisture content of the soil.

In addition to rapid surface runoff due to inadequate surface cover, conventional (traditional) farming practices involving frequent plowing and tilling in preparation of the seed bed have also shown to be highly destructive of soil quality, hence reducing the soil's long term production capacity (Dumanski and Peiretti, 2013). Therefore, in order to protect the soil resources and prevent land degradation, the traditional approaches with conventional tillage must be replaced by conservation farming practices based on continuous soil surface cover by using appropriate procedures such as reduced tillage, minimum tillage and other conservation techniques. These may include no-tillage systems that would maintain continued soil surface cover and help sustain soil productivity and maintain the integrity of the environment, if adapted to the site ecosystem. Although these concepts already exist and have shown much promise towards achieving a more sustainable agriculture, they are also highly knowledge dependent and require management skills for agricultural sustainability and long-term economical well being (Dumanski and Peiretti, 2013). For example, under no-tillage farming systems, soil disturbance is virtually eliminated. This has been shown to be the most effective technology in mitigating many of the negative on-farm and off-site effects of conventional tillage, principally erosion by surface runoff (Dumanski and Peiretti, 2013). The adoptability of the procedures however, may differ from place to place based on the climate as well as other ecosystem conditions. Unlike other conservation farming practices, the no-tillage technique is more management intensive and its success or failure is knowledge based with respect to the soil as well as other ecosystem conditions where no-till is practiced. Also, no-tillage systems normally require four to five years or more of continuous no-tillage, complemented with crop rotations and leguminous cropping, for the soils to become stabilized (Golabi et al., 1995) and hence maintain a sustainable, economically viable productivity for small scale farmers. No-tillage farming requires much education and knowledge and innovative farmers who are able to adjust to the evolving conditions and ensure the sustainability of their farming operations within their limited means and resources. As stated by Dumanski and Peiretti (2013), the various approaches to soil conservation, including no-tillage systems, are not separate concepts, rather components of a continuum of conservation approaches applicable at different conditions and adoptability levels. Also, local farmer's knowledge, innovation and adoptability, research backstopping, as well as the support of the community and farmers association are all necessary elements of adoption for any new technique and innovative agricultural practices such as no-tillage and conservation farming.

Considerable research has been published on the various components of conservation-tillage practices and reduced-tillage systems (Carter and Rennie, 1982; Blevins et al., 1983; Mielke et al., 1986; Radcliffe et al., 1988; Golabi et al., 1995; El-Swaify, 1999; El-Swaify, 2001). As numerous workers have reported, no-tillage and reduced tillage practices can increase site productivity through soil-erosion control and improvement of soil properties such as enhanced organic matter content, structural improvement, water-holding capacity, nutrient availability, and Cation Exchange Capacity (Hargrove et al., 1982; Groffman, 1985; House and Parmelee, 1985; Groffman, et al., 1986). It has also been reported (Al-Kaisi and Yin, 2005) that conservation tillage is regarded as one of the most effective agricultural practices for reducing soil CO_2 emission to the atmosphere from agricultural soils. Increased atmospheric carbon dioxide (CO_2) has been considered a major contributor to global warming (Al-Kaisi and Yin, 2005). Carbon loss from soil to the atmosphere as either CO_2 or other gases has been exacerbated due to inappropriate tillage practices (Al-Kaisi and Yin, 2005). Otherwise, the soil can function as a net sink for sequestering atmospheric CO_2 through appropriate soil and crop management (Al-Kaisi and Yin, 2005). However, the total soil carbon (TC) storage capacity and carbon dynamic is complex and often variable, especially during the first stages of conservation tillage systems or within a short-term no-tillage practices when the soil matrix is not yet stabilized (Al-Kaisi and Yin, 2005).

The greatest challenges for conservation-tillage production therefore, is providing an economical nitrogen supply for non-leguminous crops, as well as dealing with severe weed problems. The relatively long growing season and adequate rainfall in Guam and the islands of Micronesia permit continuous growth of legumes for supplying nitrogen to subsequent crops. Hargrove and Frye (1987) have reported that a well-adopted legume