Keynote Speech

No-Tillage Farming for Sustainable Biomass Production

Dr. Masakazu Komatsuzaki
College of Agriculture, Ibaraki University, Japan
komachan@mx.ibaraki.ac.jp

Introduction

Sustainable biofuel production systems are desirable for building sustainable societies, and will have an important role for producing biofuel feedstock in this century. However, there are several obstacles that need to be overcome for producing biofuel, including the energy required for production of the biofuel feedstock. In general, tillage consumes 30% of total energy required for crop production and no-tillage significantly reduces energy consumption. Developing successful no-tillage systems is thus important for reducing energy consumption and maintaining soil organic matter in sustainable biofuel production.

Sweet sorghum as a new bio fuel crop

In recent years, bio-ethanol production derived from biomass (corn, sugarcane, *etc.*) has increased remarkably, especially in North and South America. By 2010, approximately 19,500 mega gallons of bio-ethanol had been produced in the world (Renewable Fuels Association, 2010). In Japan, "on-site models" (small scale/dispersion types) for biofuel crop cultivation in various areas are recommended. One of the most promising biofuel crops is sweet sorghum (Sorghum bicolor Moench), which has been used as a forage crop. Its many advantages include considerable sugar production in its stem, a short growing period, wide cultivation area (from the tropics to throughout the temperate zone), and no adverse effects on local food crop production and economies. In addition, sweet sorghum has a high ability to absorb nutrients from surrounding soil, including excess nitrogen and phosphorus. Sweet sorghum cultivation has therefore attracted much attention not only as a forage and bio-remediation crop, but also for its potential for biofuel production.

The strategy for sustainable biofuel production should be compatible with increasing soil organic matter (SOM) to improve soil quality for sustaining biomass productivity and to reduce purchased inputs for production. These techniques will usually reduce chemical or organic nutrient inputs. In addition, cultivation of cover crops is a more attractive alternative because they add organic matter to the soil. These technologies should be used for biofuel production, but proper management techniques for no-tillage with cover crop are still not well understood for biofuel production.

Tillage systems for sustainable biomass production

Conventional tillage systems in Japan start with plowing to a depth of 30 cm with a moldboard plow or cultivating to a depth of 15 cm for rotary tillage in the fall or spring. Soils are then disked or cultivated in the

Table 1. Sweet sorgum prduction using No-tillage system

Sweet Sorghum	Planting density	Height	Stems	Sugar content	fresh weight	Dry weight	Ethanol yield
	plants ha^{-1}	cm		Brix%	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}
Big suger	104,170	366	14.5	13.1	72,730	30,300	2,742

Potato cultivation

No-tillage seeding

Bio fuel production

Fig. 1 Sweet sorghum production using No tillage seeder following potato production in Ibaraki University, Japan.

spring once or twice to further break down aggregates and smooth the soil surface before planting (Gu *et al.* 2002). These treatments ensure the germination of crop seeds and enhance the mineralization of SOM; however, many scientists and farmers have recently recognized that the conventional tillage system stimulates decomposition of SOM and increases the potential for soil erosion by wind and water.

The effect of cover crop residue biomass on the power consumption of the no-tillage seeder is considerable. The power consumption increased with increasing cover crop residue biomass at all three PTO speeds. However, the increase in power consumption was higher at high speed than at medium and low speed. In addition, the power consumption was always highest at high speed and lowest at low speed for the same amount of cover crop residue biomass (Fig 2).

Conservation tillage systems, including no-till, leave more surface residue because the soil is not turned over. These systems create less potential for soil erosion and therefore conserve SOM. Many studies on ecosystems under long-term management involving conventional tillage (CT) and no-tillage (NT) practices have demonstrated that tillage causes a substantial decrease of SOM content and mineralization of carbon. Japanese soils, especially Andisols, usually show great soil organic carbon (SOC) stock which ranges from 30 to 60 g kg^{-1};

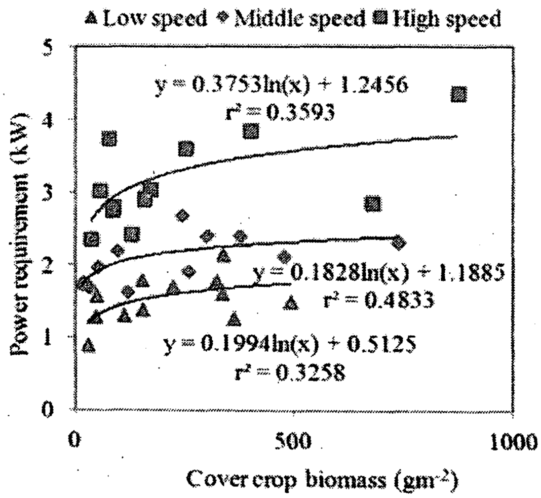

Fig. 2 Effect of cover crop residue biomass on power consumption of no-tillage seeder at different PTO rotational speeds (*P<0.05)

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Cover crops are grown in addition to primary cash crops for the purpose of erosion control, organic N enrichment, conservation of soil organic matter, scavenging soil residual N, and nematode control (Komatsuzaki 2004). Ismail *et al.* (1994) evaluated the long-term effects of tillage in continuous corn cropping with a rye (*Secale cereale* L.) cover crop in Kentucky, USA. SOC in the top 30 cm did not change from 1975 to 1980, but increased substantially from 1980 to 1989. Komatsuzaki and Mu (2005) evaluated the effects of tillage in continuous field rice cropping with rye and hairy vetch (*Vicia villosa Roth*) cover crops in the Kanto region of Japan. SOC in the top 0 to 2.5 cm increased compared with winter fallow 2 years after adopting cover cropping; however, other soil layers did not change.

Carbon and Nitrogen Dynamics for sustainable biomass production

The maintenance and improvement of soil quality in croplands are critical to sustaining agricultural productivity and environmental quality for future generations. A fertile soil provides essential nutrients for crop plant growth, supports a diverse and active biotic community, exhibits a typical soil structure, and allows for undisturbed decomposition. In general, an increase in soil organic matter (SOM) increases crop yield response and conserves water quality, thus improving soil quality. A study of soils in Michigan demonstrated potential crop-yield increases of about 12 % for every 1 % of organic matter (Magdoff 1998). Decreasing SOM, however, causes low soil fertility and low cation exchange capacity, resulting in additional fertilizer inputs to maintain economical yield.

SOM, which includes a vast array of carbon compounds originally created by plants, microbes, and other organisms, helps to maintain soil fertility, and plays a variety of roles in the nutrient, water, and biological cycles. SOM is also critical for its function to support crop growth naturally, and provides a place for water, air, and biological ecosystems to exist in the soil. Proper soil management also has great potential to contribute to carbon sequestration by transferring atmospheric CO2 into long-lived pools and storing it securely so that it is not immediately re-emitted. Soil management practices that improve soil quality through enhancing SOM and fertility will become more widespread, because soil management also determines the level of food production, and, to a great extent, the state of the global environment, and the current pressure on the land resources of the world is enormous (Komatsuzaki and Ohta, 2007).

The strategy of soil management for sustainable agro-ecosystems should be compatible with increasing SOM to improve soil quality for sustaining food productivity and to control soil residual nutrients that aggravate environmental problems. Cover cropping is a unique technique for improving the N cycle in cultivated soil because it scavenges the soil residual N and turn residuals into nutrients for subsequent crops (Komatsuzaki and Ohta, 2007). It has been reported that rye cover crops accumulated soil N as the soil residual N level increased, soil inorganic N distribution showed that inorganic N concentration at a 60–90 cm depth was significantly low for rye compared with hairy vetch and fallow at cover crop growth termination, and this soil inorganic N reduction was observed to occur year-round. In addition, no-till with rye cover crop showed the highest increase ratio of soil carbon storage, although winter fallow showed a decrease in soil carbon storage during the 9 of the years experiment (Fig.3).

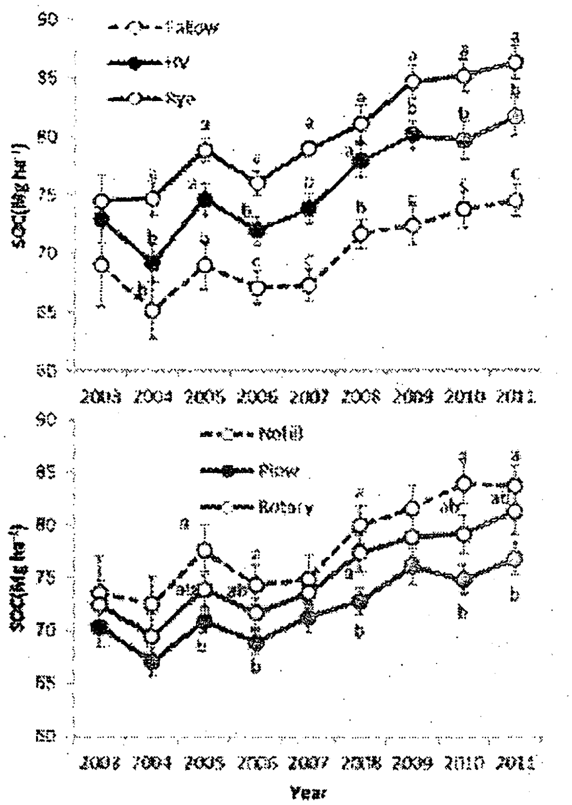

Figure. 3 Soil organic carbon (SOC) levels in the 0-30 cm layer, high N rate, 2003-2011 by (a) tillage system and (b) cover crop management. Points lettered different in a given year denote significant differences at $p<0.05$ (Fisher's PLSD test).

Conclusion

Concern for soil management will become more widespread and noticeable because further increases in agricultural output are essential for promoting equity and maintaining global political and social stability. Soil micro- and macro organisms contribute a wide range of essential services to the sustainable function of all ecosystems by acting as the primary driving agents of nutrient cycling; regulating the dynamics of soil organic matter, soil carbon sequestration and greenhouse gas emission; modifying soil physical structure and water regimes, enhancing the amount and efficiency of nutrient acquisition by the vegetation; and by enhancing plant health. To meet the growing demand for and pressures on land and water resources, it will be necessary to develop and adopt eco-specific, eco-friendly and system-based soil management practices. However, for conventional agricultural practices, the planned biodiversity above-ground is reduced with the intention of increasing the economic efficiency of the system. This impacts the associated biodiversity of the ecosystem - micro-organisms and invertebrate animals both above and below ground lowering the biological capacity of the ecosystem for self-regulation and thence leading to further need for substitution of biological functions with agrochemical and petro-energy inputs.

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