CHAPTER 2
REVIEW OF LITERATURE

1. Introduction

Sugar is produced since time immemorial and significantly appeared during Sukhothai period with Sukhothai, Phitsanulok and Kamphaengphet provinces as the production centers. During the Ayudhya period, export of indigenous simple brown sugar (muscovado) to Japan began and during 1822 in the Rattanakosin period, the exports touched 5000 metric tons per year. Since then Thailand has been one of the key exporter of sugar (Mitr Phol Group, 1999). Thai sugar industry went though various stages of development with the introduction of sugar industry acts leading to a very significant development. Presently, sugar industry not only generates employment for more than 600,000 people, it has brought about overall development of the country by diversification into electricity generation and Ethanol production.

In an era of rapid technological changes and ever increasing economic constraints, it is easy to overlook, or take it for granted, many of the basic components which contribute to a sustainable sugarcane cropping system. The average amounts of nutrients removed by one crop of sugarcane per hectare is 136 kg nitrogen, 21 kg phosphorus, 139-276 kg potassium, 34 kg sulfur, 0.09 kg copper, 0.47 kg Zinc, 7 kg Iron and 3.81 kg manganese (Calcino, 1991). The focus is often on use of latest technological advance to maximize economic returns High inputs of fertilizer, chemicals, water and improved varieties are combined to maximize productivity. The productive capacity of the soil is often not taken into consideration.. It is clear that monoculture, excessive tillage, low inputs of organic matter, use of herbicides and insecticides, heavy traffic, and high inputs of nitrogen has resulted in unhealthy soils.

Most soils in Northeast Thailand have their origin from weathering of sandstone which is low activity clay (kaolinite) and high hydrate oxide of Fe and Al. This has resulted in whole region being sandy soil and three fourth classified in order Ultisol and Oxisol (acid tropical soils). The coarse texture with lower amounts of clay particle content and acid soil of Ultisol and Oxisol renders low crop productivity. Low

CEC in sandy soil affects low nutrient and organic matter adsorption. Phosphorus fixation occurs as oxide of Fe and Al resulting in Al toxicity (Maneewan *et al.*, 1998). The low soil productivity in Ultisol and Oxisol can be overcome by improving CEC and organic matter in soil. Soil organic matter can be improved by organic material application. The problems being slow decomposition rate, high leaching, and low clay activity in tropical climate which should be applied on aregular basis.. High activity clay material application can improve CEC which in tern can adsorb cation of nutrient and organic matter tightly with clay colloid.

2. Sugarcane production

The cane production is related to variety and crop management as detailed

2.1 Sugarcane classification and ecology

Sugarcane belongs to the genus *Saccharum* and is a grass, like most of the world's grain crops. However, instead of storing starch in seed like the grain crop, sugarcane has evolved to store sugar (sucrose) in its stalk. The archetypal soft, sweet chewing "noble canes" belong to the species *Saccharum officinarum*, which appears to have evolved from its wild relatives in Papua-New Guinea. The very vigorous but low-sugar species is *S. spontaneum* that is found around streams and river throughout Papua-New Guinea and Southeast Asia. The heavier stalked but still on high sugar and high-fibred species, *S. robustum*, is found only in Papua-New Guinea. *S. edule*, is also not very sweet but produces an edible flower, like an elongated cauliflower, which is a delicacy throughout Melanasia and Polynesia. Outside Papua-New Guinea, two other species, *S. sinense* and *S. barberi*, were widely used as sugarcane in China and India. The sugarcane plant is composed of stalks, leaves, roots and flowers. Each has an important role in crop growth, crop ripening and production of new varieties (Hogarth and Allsopp, 2000; Hunsigi, 1993 and Clement, 1901).

2.2 Sugarcane growth and requirement

The growth of sugarcane can be divided into five phases (Bull, 2000) (1) Germination where the plant is established and tillers initiated (2) Early growth where the leaf canopy is established and maximum growth or elongation of the storage organ (the stalk) occurs (3) Maturation where stalk elongation slows down and sugar storage or ripening dominates (4) Flowering where vegetative growth ceases and an arrow (flower) is produced (5) Ratooning where stalks are harvested and crop re-growth occurs from underground buds on the severed stalks. The growth phases constitute the life cycle of sugarcane in its normal production and they are affected by environmental factors.

Sugarcane can grow from sea level to 1,300 m above mean sea level. The slope of land should be less than 3 percent (Field Crops Research Institute, 1983). Optimum condition being tropical and dry during growth (20° to 38°C) and cool during ripening period (10°to 20°C) (Humbert, 1968 and Blackburn, 1984). The soil should be at least 50-80 cm deep and ground water depth more than 160 cm (Sooksathan, 1980 and Sooksathan and Poolkate, 1984). Soil should be loose, well aerated and well drained. Bulk density should be less than 1.2 g cm^{-3} with texture of either loam, silt loam or clay loam. Chemical soil properties include pH of 5.6-7.3, organic matter 1.5-2.5 percent, available phosphorus 10-20 ppm, exchangeable potassium 80-150 ppm, calcium 0.55-1.25 $cmol_c\,kg^{-1}$, magnesium 0.1-0.25 $cmol_c\,kg^{-1}$, copper more than 0.2 ppm, zinc more than 0.6 ppm, cation exchange capacity more than 15 $cmol_c\ kg^{-1}$, electrical conductivity less than 2.5 dS m^{-1} and base saturation more than 75 percent (Prammanee, 2001).

The quantity of nutrients removal depends on soil type, weather condition and fertilizer practices (Hogarth and Allsopp, 2000). Calcino (1991) reported the average of amount nutrients removal by one sugarcane crop at 136 kg of nitrogen, 21 kg of phosphorus, 220 kg of potassium, 39 kg of calcium, 36 kg of magnesium, 34 kg of sulfur, 0.09 kg of copper, 0.47 kg of Zinc, 7 kg of Iron and 3.81 kg of manganese per hectare. Generally, the crops in the higher productivity region remove higher nutrients per hectare but no simple relationship exists between soil fertility, fertilizer application and nutrient removal by the crop.

2.3 Sugarcane planting and management

In Thailand, sugarcane planting is carried out in 2 seasons.

(1) Early rainy season in clay soil of Central, West and Northeast regions in irrigated and high clay content in soil texture zone (20% of Kingdom) where the cane is planted during February to April. Most farmers use farm machinery, such as

planter, fertilizer applicator, weed control equipment and harvester. The normal spacing is about 1.5 m. planting. However, some area is planted in rainfed area during April to June with narrow row spacing (0.9 –1.0 m.) or double row planting (0.25 x 1.4 m.) is practiced to maximize the yield.

(2) Late rainy season (in sandy soil of Northeast and eastern regions) where the cane planting is carried out during October to December. This zone for a successful crop should receive more than 1,200 mm per year of rainfall and appropriate distribution especially during February to April which are critical crop growth phases.

The management by fertilization is normally applied at planting to encourage early root development and plant growth. After the cane is planted, subsequent operations are aimed at controlling weeds, promoting tillering by second fertilization, and assisting emergence through breaking of surface crusts. Plant protection is an important factor in maintaining high yields of high-quality sugar in sugarcane cropping. Harvesting and transportation in Northeast Thailand is earlier than other regions. Management of the ratoon crop is partly dependent on the type of harvesting systems employed, a burnt-cane or green-cane system. The important operations for successful ratooning are stubble shaving, ripping and chiseling and gap filling.

2.4 Sugarcane production in Thailand

The sugarcane planting area in Thailand has increased from 65,344 ha in 1981/82 to 1,170,850 ha in 2003/04. The cane production was 23.92 million tons during 1981/82 and increased to 64.97 million tons during 2003/04. The sugar sweetness value (brix) slightly increased and the total sugar production at 98 Pol per one equivalent cane ton at 10 CCS (commercial cane sugar) increased from 94.02 kilograms in the production year 1982/83 to 108.71 kilograms in production year 2003/04.

Sugar export also increased parallel with its production. Sugar export volume increased from 1.54 million tons in 1983 to 3.14 million tons in 2003. The sugar importing countries from Thailand are Indonesia, Japan, Malaysia, China, South

Korea, Philippines, Russia and others with 0.88, 0.48, 0.42, 0.17, 0.14, 0.02, 0.03 and 9.93 million ton sugar respectively during January to July 2004.

3. Ultisols in Northeast of Thailand

The total area of Thailand is about 550,000 km^2 of which agriculture land use is about 180,000 km^2. Northeast has agricultural land use about 85,000 km^2 (47 percent of whole Kingdom) (Cholitkul, 1987). The Ultisols occupy about 200,000 km^2 of the whole kingdom (Changpri, 1987). Ultisols have developed over deeply weathered regolith on diverse rock types, or on colluvium and alluvium originating from these materials (Kheoruenromne, 1991). Kaolin is present in all these soils and is commonly the dominant clay mineral (Yoothong *et al.*, 1997). Many soils in Thailand are inherently very low in chemical and physical fertility and many of the management problems may be related to the dominance of kaolinite in clay fraction (Suddhiprakarn *et al.*, 1985). Most soils in Northeast are sandy having low fertility and low water holding capacity which results in low productivity soil. The texture of soil is sandy to loamy at 1-3 meter depth. In some areas, there may be a lateritic layer on the top 0.50 m layer of soil. Soil color ranges from reddish yellow to reddish brown and gray (Na Nakorn, 1987). 80 percent of soil in this region is mainly structured with sand whereas another 13 percent is composed of shallow laterite (Mitsuchi *et al.*, 1986). Soil is easily eroded, infertile, and low water holding capacity, so plants are water deficient during dry spell. Soil reaction tends to be acid to highly acid with pH of 4-6. Organic matter ranges from 0.3 to 1.0 percent, which is considerably low. Cation exchange capacity (CEC) ranges from 2.4 – 10.0 cmol$_c$ kg^{-1} (Impitak and Vityakon, 1989). Total phosphorus ranged from low to medium level, 30-50 ppm. The total potassium is very low-ranged 300-900 ppm (Cholitkul *et al.*, 1987), while exchangeable iron and manganese was 35 and 26 ppm respectively (Vibulsukh *et al.*, 1988).

Korat soil series (Kt) is a major series in Northeast with 20.05 percent of the whole region. Kt is alluvium in middle terrace soils in family of fine-loamy siliceous, isohyperthermic, Oxic Paleustults with soil color grayish brown (10 YR 5/2) to pinkish gray (7.5 YR 6/2) in topsoil and brown (7.5 YR 5/4) to light brown (7.5 YR 6/4) in subsoil and sandy loam texture. The chemical properties of Kt are acid soils, low organic matter (0.2-1.2 %), low cation exchange capacity (2.9-6.0 $\text{cmol}_c\ \text{kg}^{-1}$), low base saturation (23-78%), low calcium (0.4-3.3 $\text{cmol}_c\ \text{kg}^{-1}$), low magnesium (0.4-0.7 $\text{cmol}_c\ \text{kg}^{-1}$), very low potassium (0.2-0.3 $\text{cmol}_c\ \text{kg}^{-1}$), low sodium (0.2-0.3 $\text{cmol}_c\ \text{kg}^{-1}$) and low available phosphorus (5.3-12.0 ppm) (Keerati-Kasikorn, 1984).

4. Sandy soil degradation

4.1 Definition of sandy soil

Sandy soils are referred to coarse textured soils. Their basic soil textural classes names are sand and loamy sand texture deserve special considerations since they have a larger percentage of sand fractions that adversely affect their agricultural potentialities. The definition of these basic soil texture class names as given in the publications by Canada Department of Agriculture (1972), Soil Science Society of America (1971) and United State Department of Agriculture (1960) define sand texture is soil material containing at the upper limit 85 to 90 percent sand, the percentage of silt plus 1.5 times the percentage of clay not exceeding 15 and loamy sand texture as soil material containing at the upper limit 85 to 90 percent sand, and the percentage of silt plus twice the percentage of clay not exceeding 30. Sandy soils are non-sticky, non-plastic when wet and have loose consistency when dry. Most soil separates of the sands and loamy sands are noncoherent and remain as single grains, especially in the absence of organic matter or other binding compound. Israelson and Hansen (1962) found high apparent specific gravity of these soils (1.55-1.80) reflected in their low total porosity (32-42 percent) which is less than that of finer textured soil. Upon deformation, loose sand decreased in volume due to sliding or rolling down into a dense state while dense sand increases its volume accompanying upon the stability of cohesiveness materials. Sandy soils are very low specific surface area. Sandy soils have low ability to retain moisture; their available water range (FC-PWP) is rather norrow (4-6 percent). The infiltration rate of sandy soils (2.5-25 cm hr^{-1}) could be 250 times more than that of clay soils (0.01-0.1 cm hr^{-1}). Redistribution of moisture after cessation of infiltration usually proceeds at a faster rate and even to a greater depth in coarse textured soil than in a finer one (Soliman, 1968). Upward water movement in sandy soils does not proceed at a fast rate. Since wet, sandy soils have a relative higher hydraulic conductivity, their ability to deliver water to evaporative zone at the soil surface is greater and is mainly determined by the meteorological condition. On the other hand, a dry sandy soil is a poor transmitting medium for capillary water and consequently upward water movement and evaporation losses are marginally reduced. Water movement could proceed, however, by vapour diffusion (Massoud, 1964). It is an accepted fact that most sandy soils have too much aeration at the expense of inadequate water holding capacity. Air permeability was found to decrease with decreasing particle size and increasing bulk density (Elgabaly and Elghamry, 1970).

The agricultural potential of sandy soils is hampered by their low water-holding capacity, weak structure and low organic matter content, low inherent fertility and low micro-biologic activity and their association with salic, calcic or gypsic or duric physio-chemical conditions. The occurrence of compact layers (e.g. calcic, gypsic, duragid and duric) of varying thickness and depths impede their natural drainage. All constraint affects plant growth and restricts crop productivity. Ricaud (1977) showed that there was a severe reduction in cane yield in the sandy soils of Louisiana due to soil compaction. This is confirmed by the findings of Monteith and Banath (1965) who stated that as bulk density increased, mechanical impedance became dominant. Dense soil can be reduced the foliar concentration of nutrients and their accumulation in plant (Trouse and Humbert, 1961). In the studies of Juang and Uehara (1971) found soil compaction reduced phosphorus and potassium uptake by cane as well as reducing the dry weight of roots.

4.2 Definition of soil degradation

Soil degradation is temporary or permanent lowering of the productive capacity of soil (Scherr, 1999 and UNEP, 1992). Soil degradation may be defined as the loss of utility or potential utility or the reduction, loss or change of features or organisms which can not be replaced (Barrow, 1991). Degradation processes include erosion, compaction and hard setting, acidification, declining soil organic matter, soil fertility depletion, biological degradation and soil pollution (Lal and Stewart, 1990). Soil degradation implies a regression from higher to a lower state and deterioration in productive capability (FAO, 1983).

4.3 Type of soil degradation

The varied processes of soil degradation have been grouped as below (FAO, UNDP and UNEP, 1994):

4.3.1 Water erosion: Water erosion covers all forms of soil erosion by water, including sheet, rill and gully erosion. Human induced intensification of land sliding caused by vegetation clearance, road construction, etc.

4.3.2 Wind erosion: Wind erosion refers to loss of soil by wind and occurring primarily in dry regions.

4.3.3 Soil fertility decline: The soil fertility decline is used as a short term to refer to what is more precisely described as deterioration in soil physical, chemical and biological properties. Whilst decline in fertility is indeed a major effect of erosion, the term is used here of cover effects of processes other than erosion. The main processes involved are:

4.3.3.1 Lowering of soil organic matter decline with associated of soil biological activity.

4.3.3.2 Degradation of soil physical properties (structure, aeration and water holding capacity), as brought about by reduced organic matter.

4.3.3.3 Adverse changes in soil nutrient resources, including reduction in availability of the major nutrients (nitrogen, phosphorus and potassium), onset of micronutrient deficiencies and development of nutrient imbalances.

4.3.3.4 Building of toxicities, primarily acidification through incorrect fertilizer use.

4.3.4 Water logging: Water logging is the lowering inland productivity through the rise in groundwater close to the soil surface. Also included under this heading is the severe form, termed ponding, where the water table rises above the surface. Waterlogging is linked with salinization, both being brought about by incorrect irrigation management.

4.3.5 Salinization: Its board sense, to refer to all types of soil degradation brought about the increase of salts in the soil. It thus covers both salinization in its strict sense, the build-up of free salts, and sodification, the development of dominance of the exchange complex by sodium. As human-induced processes, these occur mainly through incorrect planning and management of irrigation schemes. Also covered is saline intrusion, the incursion of seawater into coastal soils arising from over-abstraction of groundwater.

4.3.6 Lowering of the water table: Self-explanatory from land degradation, brought about through tube well pumping of groundwater for irrigation and exceeding the natural recharge capacity. This occurs in areas of non-saline groundwater. Pumping for urban and industrial use is a further cause.

4.3.7 Deforestation: The occurrence of deforestation is widespread and extremely serious in the region. Deforestation is also discussed as a cause of erosion.

4.3.8 Forest degradation: This is the reduction of biotic resources and lowering of productive capacity of forests through human activities.

4.3.9 Rangeland degradation: This is the lowering of the productive capacity of rangelands.

4.3.10 Acid sulphate formation: A serious but localized form of degradation which may occur on drainage of coastal swamps

4.3.11 Soil pollution: Industrial or mining effluents to the atmosphere and rivers or groundwaters were polluted. This is an important concern in the region but is strongly localized.

4.3.12 Soil destruction through mining and quarrying activities: The failure to restore soil after extraction. The same remarks apply as for soil pollution.

4.3.13 Urban and industrial encroachment onto agricultural land: The projected increase in urbanization, this will continue to be a substantial cause of loss of agricultural land, but it is a different problem from land degradation.

4.3.14 Effects of war: Land degradation on a substantial scale through effects of war has been reported and destruction of irrigation schemes.

4.3.15 Potential effects of global climatic change: It is possible that will lead modifications of the general atmosphere circulation with consequent changes in rainfall.

4.4 Causes of soil degradation

Soil degradation is usually a complex process in which several features can be recognized as contributing to a loss of productive capacity. It is convenient to define the causes of soil degradation (FAO, UNDP and UNEP, 1994):

4.4.1 Deforestation of unsuitable land: Deforestation becomes a cause of degradation first, when the land that is cleared in steeply sloping, or has shallow or easily erodible soils; and secondly, where the clearance is not followed by good management. It is the leading cause of water erosion in steeply sloping humid environments. It is also a contributory cause of wind erosion, soil fertility depleting and salinization.

4.4.2 Overcutting of vegetation: Rural people cut natural forests, woodlands and shrub lands to obtain timber, fuel wood and other forest products. Such cutting becomes unsustainable where it exceeds the rate of natural regrowth. It is the leading cause of water erosion, wind erosion and salinization.

4.4.3 Shifting cultivation without adequate fallow periods: In the past, shifting cultivation was a sustainable form of land use, at a time when low population densities allowed forest fallow periods of sufficient length to restore soil properties. Population increase and enforced shortening of fallow periods has led to it becoming non-sustainable. It is a cause of water erosion and soil fertility decline.

4.4.4 Overgrazing: The grazing of natural pastures at stocking intensities was carried exceed the livestock carrying capacity. It leads directly to decreases in the quantity and quality of the vegetation cover. This is leading cause of wind and water erosion in dry lands. Both degradation of the vegetation cover and erosion are lead to decline soil organic matter and physical properties, and hence in resistance to erosion.

4.4.5 Non-adoption of soil-conservation management practices: The well-managed farms maintain a complete vegetation cover, which checks erosion even on steep slopes; on poorly managed farms, rainfall strikes bare soil between plants and leading in places to very severe degradation.

4.4.6 Extension of cultivation onto lands of lower potential and/or high natural hazards: The more fertile or high potential agricultural lands were the first to be occupied. Population increase has led to the widespread use of lands of lower potential which are less fertile or have greater degradation hazards.

4.4.7 Improper crop rotations: Population growth, land shortage and economic pressures, farmers in some areas have adopted cereal-based, intensive crop rotations, based particularly on rice and wheat, in place of the more balanced cereallegume rotations that were formerly found. This is a contributory cause of soil fertility decline.

4.4.8 Unbalanced fertilizer use: Soil fertility has declined, because of prolonged cultivation or erosion, farmers attempt to maintain crop yields. The primary method available for doing so is application of fertilizer in the short term; a yield response is obtained most readily and cheaply from nitrogenous fertilizer. There has been a steady increase in the ratio of nitrogen to phosphorus and nitrogen to all other nutrients. Where phosphate deficiencies have been recognized and counteracted by phosphatic fertilizer, deficiencies of other nutrients including sulphur and zinc. The short-term measure of combating fertility decline by application only of macronutrients, and particularly nitrogenous fertilizer, is leading to a greater problem of nutrient imbalance. Among the consequences is likely to be lower yield response to fertilizers.

4.4.9 Problems arising from planning and management of canal irrigation: The water table has reached soil surface and water logging occur and then evaporation of water containing salts caused to salinization. Sodification follows where sodium replaces other bases in the soil exchange complex.

4.4.10 Overpumping of groundwater: This has progressively lowered the water table.

4.4.11 Land shortage: The increasing in rural population and land shortage has led to decreases in the already small areas of agricultural land per person.

4.4.12 Land tenure: tenancy and open access resources: With no legal basis to their use, incentive to farm the land other than for immediate needs is completely lacking. This is a serious cause of deforestation followed by water erosion.

4.4.13 Economic pressures and attitudes: Small land holdings lead to severe economic pressures on farmers, to obtain sufficient food and income. Because of such pressure in the short term, labor, land and capital resources cannot be spared to care for the land, for example green manuring or soil conservation structures.

4.4.14 Poverty: Poverty leads to land degradation: it could almost certainly be shown that richer farmers maintain their soils better than poorer.

4.4.15 Population increase: Land shortage is the second basic cause of degradation is the continuing increase in rural, agricultural and population.

Generally, land use in this region for agriculture with monocropping for long time and no conservation and lack of soil improvement causes soil degradation very rapidly and low crop production. Although, the government agency recommends fertilizer formula for farmers for specific crop to increase yield, in practical much of chemical fertilizer applied in soil is not available to plant due to low organic matter in soil (low CEC) and low water holding capacity. Therefore, the soil cannot adsorb whole nutrient in short time after fertilization and nutrient loss by percolation into deeper zone than plant root can be taking up. Nevertheless, some fertilizers also affect to reduce water infiltration rate (Garside *et al.*, 2000).

4.5 Major factors influencing soil degradation in sugarcane cropping system

Sugarcane is grown as a long-term monoculture (same species grown continuously on the same area of land) about three years (about one plant and two ratoon crops). Hence, land is under cane for at least 90 percent of time (30 months under cane and followed by six months fallow or by another cane crop). The factors influences of sugarcane cropping system on soil degradation e.g. high nutrients removal by sugarcane crop, burnt cane harvesting causes nutrients losses, development of pests and diseases due to chemical control, heavy machinery caused to soil compaction and excessive tillage and a failure to return adequate quantities of organic matter to the system degrades organic matter status.

5. Soil improvement in degraded soil for sugarcane production system

The sugarcane production system is to be improved; we must break the monoculture, diversify sugarcane varieties, minimize chemical usage, become more reliant on legume nitrogen, improve the organic matter status of our soils, substantially reduce tillage and minimize compaction by heavy machinery.

5.1 Improving cropping system

The improvement of sugarcane cropping system viz., crop rotation, intercropping and alley cropping to break the sugarcane monoculture with either bare fallows, other annual crop species (soybean and peanuts) or mixtures of grass/legume pastures. The results strongly support better cane production following a break, and this productivity appears to be clearly associated with enhanced soil biological and physical conditions. In an experiment at Tully, when plant cane following soybean or plough out/replant was applied with either 0 or 140 kg ha^{-1} of nitrogen, a sugar yield increase of 1.5 t ha^{-1} was recorded following the soybean, which was independent of nitrogen (Garside *et al.*, 2000).

5.2 Improving soil organic matter

Organic matter is the basis of soil health. Chemical, physical and biological soil properties are all influenced by the amount of organic matter cycling in the system. The sugar industry has made a major move towards a more sustainable system by adopting green cane trash blanket.

5.3 Strategic tillage and controlled traffic

Strategic tillage offers the possibility of improved soil structure through considerably reduced tillage of the crop row and further improvements in chemical, biological and physical properties through trash blanketing. Establishment of legume fallows in the permanent cane rows can be readily achieved. Further, with such a system, it may be possible to include a legume on an annual basis while the ratoon is establishing.

6. Efficiency of organic material amendment in degraded soil

Soil organic matter is a fundamental but transient component of the soil that controls many chemical, physical and biological properties affecting ability of a soil to produce food, fiber or fuel. It is primary source of energy for the ecosystem and a temporary sink for plant nutrients in agroecosystems. Soil organic matter is important in maintaining soil tilth, aiding the diffusion of air, the retention and infiltration of water, reducing soil erosion and controlling the efficacy and rate of applied pesticides (Gregorich and Janzen, 1995).

Organic matter itself can be characterized by various fractions (e.g. microbial biomass, carbohydrates and humic acids) with specific turnover times which can impact on soil carbon storage (Gregorich and Janzen, 1995). Maintenance of satisfactory organic matter status is essential to the productivity of most tropical soils, especially in Ultisols (von Uexkull, 1982). Organic matter as a key element in the management of degraded soils is still grossly underestimated and neglected in most other tropical areas. Organic matter can play a central role in maintaining or increasing soil productivity by improving soil temperature, moisture and structure and reducing the danger of erosion.

(a) Soil temperature: The roots of most crop are sensitive to temperature above 34°- 42°C. Exposed surface soils may reach temperatures of over 50°C, when root activity stops and fine root may die. Good organic matter management (live or dead mulch) can greatly reduce soil temperature extremes.

(b) Soil moisture affects crop yields: Good soil moisture management provides the key to high yield and good fertilizer response. Organic matter, especially as mulch, increased water infiltration and reduce evaporative moisture losses; apart from stimulating root growth and improving utilization of soil moisture.

(c) Runoff and erosion: Heavy tropical rainfall can cause serious problems through surface runoff and soil erosion, especially in Ultisols. Lal (1979) showed that removal of 2.5 cm of the topsoil could result in yield losses of 40-50 percent. Structural stability against raindrop impact is very low for most Ultisols and crusts therefore form easily reducing water infiltration and increasing runoff. A soil cover of live or dead mulch can minimise the destruction of soil aggregates, the formation of crusts and runoff.

Greenland and Dart (1972) pointed out the benefits of organic matter in agricultural systems where no fertilizer was used e.g.:

(a) Provide Nutrients: Organic matter supplies most of the N and S and half of the P taken up by unfertilized crops. The slow release of N and S from organic matter by mineralization reactions has advantages over soluble fertilizers, which are leached, volatilized or fixed.

(b) Improve nutrient holding capacity: Because organic matter supplies most of the cation exchange capacity of acid, highly-weathered soils, rapid decreases in organic matter content result in marked reductions in CEC and nutrient holding capacity.

(c) Decrease phosphorus fixation: Amorphous oxides of Fe and Al form complexes with organic matter and therefore do not crystallize. Organic matter radicals blocking the fixation sites decrease P fixation by these oxides.

(d) Improve physical properties: Organic matter contributes to soil aggregation and thus improves physical properties (e.g. soil bulk density) and reduces susceptibility to erosion. Vomacil (1957) indicated that high bulk density has a significant influence on mechanical impedance and root growth with a consequent reduction in water availability and root aeration.

(e) Improve water retention properties: In Ghana, the soil water-holding capacity decreased from 57 percent to 37 percent when the soil organic matter content decreased from 5 percent to 3 percent (von Uexkull, 1986).

(f) Improve micronutrient availability: Organic matter may form complexes with micronutrients and prevent their leaching. The availability of micronutrients is also improved.

(g) Reduce Al and Mn toxicity: The formation of complexes with Al and Mn decreases their concentration in soil solution and reducing their toxicity.

(h) Enhance formation of soil aggregation and aeration: The stimulation of soil flora and fauna activity, improved physical properties through formation of stable soil aggregates and aeration channels.

(i) Control soil temperature: Provides a soil cover preventing build-up of high temperatures in topsoil and leading to root development more freely in this zone.

6.1 Effect of green manure cropping

Prammanee *et al.* (1996) stated green manure improved soil physical condition and organic matter level. Cane yields increased by using green manure in combination with chemical fertilization by increasing tillering, increased nitrogen level (71.9 kg ha^{-1}), increased cane yield from 16 to 20 t ha^{-1} in plant cane and 13 to 23 t ha^{-1} in ratoon cane. Ratanarak and Patsarnchareon (1997) also studied the effect of a combination of nitrogen fertilizer and green manure on sugarcane in sandy loam soil using farmer's fields during 1995 to 1996. They reported that green manuring increased millable cane and sugarcane yield compared to control plot. The yield of sugarcane from sword bean and pigeon pea, were 72.7 and 64.8 t ha^{-1} respectively whereas control plot yield 61.6 t ha^{-1}. Barzegar *et al.* (2002) found application of organic materials significantly increased wheat yield and increased aggregate stability, infiltration rate, water retention at less than -100 kPa and decreased soil bulk density.

6.2 Effect of farmyard manure amendment

The effects of farmyard manure (FYM) applied at 0, 4, 8 and 16 t ha^{-1} on microbial biomass C, N, turnover of P was studied in a "Typic Haplustert" soil under soybean-wheat system in Madhya Pradesh, India. At 4 t FYM ha^{-1} microbial biomass increased but further addition of FYM reduced rates of biomass turnover. The N and P contents and microbial biomass were higher under soybean than under wheat crop (Manna *et al.*, 1996). Field trials conducted using different organic manures in India showed that the application of pig manure (10 t ha^{-1}) produced highest grain yield (4.5 t ha^{-1}), followed by poultry manure and FYM which produced yields of 4.1 and 3.9 t ha^{-1} of rice grain, respectively. The increase in rice yield with organic manure was 34 to 55 percent higher over than control and 5-22 percent higher over NPK fertilizer. The moisture percentage at 0-15 cm depth was highest (19.19%) with FYM followed by pig manure and poultry manure (Gupta, 1995).

6.3 Effect of sugar mill by-products amendment

The by-products of raw sugar manufacture (filter mud, ash, mud/ash mixtures and molasses) are valuable fertilizer sources. Because of the organic nature of many compounds containing plant nutrients in mill mud, molasses and the fused condition of ash, precise information on the rate of nutrients releasing for use by the cane plant is not known. In some cases where by-products have been applied, sufficient nutrients may not be available for the succeeding cane crop and additional fertilizer may be required.

Filter cake is trash in sugarcane juice. Sugar mill electrolytes like phosphoric acid, soda ash (calcium carbonate, calcium hydroxide and magnesium carbonate), bentonite clay and polyelectrolyte are used for flocculation the trash in sugarcane juice. Then flocculate is heated and trash filtered from sugarcane juice (Meade and Chen, 1977). Trash separates into filter cake at the rate of 30 kilograms per ton cane. The filter cake is high in plant nutrient like nitrogen, phosphorus, calcium, magnesium, sulphur, essential elements, trace elements and organic matter. Anakawech (1997) and Cerri *et al.* (1988) reported about 10 percent of phosphorus from filter cake may be released during first year in phospholipids, nucleoproteins and calcium phosphate forms. The average plant nutrients in 1 metric ton of dry filter cake contains nitrogen (12 Kgs), phosphorus (8.7 Kgs), potassium (5.0 Kgs), calcium (28.6 Kgs), magnesium (3.0 Kgs), sulphur (11.7 Kgs), 60 percent of organic matter with C/N ratio of 28.0. The fresh filter cake has 79 per cent moisture. Normally, filter cake is applied to the field at the rate of 62.5 t ha^{-1}. In clay soil, incorporation of filter cake can improve soil consistency, air permeability and water drainage. In sandy soils, filter cake can improve water-holding capacity and increase plant nutrients. Filter cake can improve sugarcane germination, tillering, and prevent seed cane in drought stage. Furthermore, filter cake can prevent nematode infection (Novaretti and Nelli, 1985). Marinho *et al.* (1981) found higher filter cake application increased cane yield. Anakawech *et al.* (1979) reported that sugarcane yield can be increased by filter cake application at the rate of 31.3 t ha^{-1} (gained 50.9 t ha^{-1} in plant cane and 59.1 t ha^{-1} in first ratoon cane). Rungrattanakasin *et al.* (1995) reported that higher application of filter cake at the rate of 37.5 t ha^{-1} can produce more cane yield of 86.3 t ha^{-1}. Sruttaporn and Sangsila (1988) found that use of filter cake (12.5-37.5 t ha^{-1}) with fertilizer formula 15-15-15 (625 kg ha^{-1}) did not affect millable cane, yield and commercial cane sugar in plant cane, but can improve soil fertility. Sillapaprommas *et al.* (2000) found filter cake (125 t ha^{-1}) along with fertilizer 15-15-15 (312.5 kg ha^{-1}) can increase cane and sugar yield. Jongrauysub *et al.* (2001) found that application of filter cake 50 t ha^{-1} can increase sugarcane yield, micropore distribution, available moisture content and decreased soil infiltration but bulk density of soil did not decrease. Several studies have convincingly shown that filter cake is an excellent phosphorus source. Filter cake has organic matter, leads to better nitrogen nutrition, soil ameliorant, increasing the calcium level and decreasing exchangeable alunimium in acid soils and promotes the CEC (Hunsigi, 1993).

Another by-product reconceived from sugarcane mill is bagasse. After juice has been extracted, cane yields about 30 percent bagasse (50% on a wet basis). The average plant nutrients in 1 metric ton of dry bagasse is nitrogen (0.40 kilograms), phosphorus (0.15 kilograms), potassium (0.44 kilograms), cellulose 47 percent, lignin

19.5 percent, density 160 kg m^{-3} (Land Development Department, 2003 and Anonymous, 1998). The average moisture of bagasse is around 50 percent. Thumthong *et al.* (1993) reported bagasse @ 25 t ha^{-1} composite with fertilizer formula 15-15-15 @ 625 kg ha^{-1} increased the yield of cane by 25.7 percent. Nevertheless, Thumthong *et al.* (1992) found in organic material amendment trial with bagasse 37.5 t ha^{-1} reduced millable cane and polarity of cane juice. Sruttaporn *et al.* (1985) found application of bagasse @ 6.25 t ha^{-1} along with fertilizer formula 12-10-15 rate 625 kg ha^{-1} could improve millable cane and yield. Prammanee *et al.* (1992) stated bagasse could reduce toxicity of saline soil. The effectiveness of different organic materials (farmyard manure, composted bagasse and wheat straw) on improving soil physical properties was similar. Wheat grain and stubble yield progressively increased as the rate of organic materials increased. The effectiveness of composted bagasse, farmyard manure and wheat straw on improving wheat grain yield was 22, 14 and 3 percent and wheat stubble yield was 26, 17 and 4 percent over the control (Barzegar *et al.*, 2002).

7. Efficiency of clay material amendment in degraded soil

Clay minerals are the fine-grain part of geology. Clays were initially defined as consisting of grain size less than 2 μm in diameter. Clay minerals were used for producing building materials and ceramics. Their chemical properties (internal and external surfaces) have many uses depend on their grain size and shape properties (Velde, 1992). The essential chemical properties of clay soil are polymerization, hydrogenation and hydrolysis. The advantage of the absorption characteristics caused of swelling clay. Polymer absorption with smaller organic molecules can be inserted between the swelling layers of clays. In polymer absorption, only the clay surface is involved, not the interlayer position. The hydrated clay complex contains interlayer cations surrounded with water molecules. The cations satisfy the negative charge on the clay surface through the hydrogens of the coordinated water molecules. The organic molecules refixed to sites on the basal oxygen surface of the tetrahedral of the clays by van der Waals or hydrogen bonding. Several mechanisms are involved in adsorption of organic compounds by clay minerals, the main ones being: 1) physical adsorption, or van der Waals forces, these forces result from fluctuations in the electric charge density of individual atom 2) electrostatic attraction or chemical adsorption, occurs through the process of cation exchange or protonation 3) H-bonding, is a linkage between two electronegative atoms through bonding with a single H^+ ion and 4) coordination complexes, the metal ion forms a bridge between the organic molecule and the soil constituent (Stevenson, 1994). Puttaso (2003) showed through tendency that bulk density decreased with increased clay particles that can induce the micropore in soil which can keep more moisture.

Smectite are naturally occurring 2:1 layer silicate clays that have high permanent negative charge due to isomorphous substitution which occurred during formation of clays. These materials have high CEC which is often dominated by essential cations such as Ca and Mg. When these materials are added to soils they are able to increase the nutrient holding capacity of soils and therefore reduce potential losses of nutrients through leaching.

Fine particles like Nile silt are directly or indirectly applied to the soil with irrigation water, organic manures and composts or in a dry form. This practice is widely known and applied by Egyptian farmers in sandy soil regions. Although application of organic matter to the sandy soil has the same effect as application of Nile silt, but organic matter is decomposed and has to be added frequently. Ahmad (1967) showed that mixing 1,300 g/pot of Nile silt and 130 g/pot of wheat straw with the surface 15 cm of the sandy soil in a pot experiment increased the dry weight of maize plants from 88.7 to 150.6 g/pot and of barley plant from 38.5 to 62.3 g/pot respectively. That also found in worked in Thailand covered of sandy soils with clay soils that soil have much higher nutrient uptake and release rates (Vibulsukh *et al.*, 1986). According to a soil survey by Mitsuchi *et al.* (1986), Northeast has some clay under the lateritic horizon layer. Their idea is to top dress this clay on sandy surface soils in the areas around water reservoirs by using clay excavated.

The montmorillonite clay addition to the soil was studied by Milarch (1997) and found tomato height increased by 14.6 percent (compare with control), greater in opening blossoms of plants maturity 190 percent and 400 percent more yield after planting 67 days. Milarch (1998) also found the combination between montmorillonite clay and paramagnetic rock produced more shoots of Sudan sorghum 65 percent than either soil supplement alone. In addition, it produced 88 percent greater total green mass than the montmorillonite clay alone and 131 percent more than the paramagnetic rock alone (Milarch, 1998). Similarly, Ottgen (1999) investigated montmorillonite clay mixed with compost produced more speed and rate of turf grass germination when compared to a conventional fertilizer. The result of Noble and Ruaysoongnern (2002) imposed bentonite plus compost increase the CEC in the plough layer by 1 to 2 cmol_c/kg. The clay materials and compost application can maintain soil fertility and soil productivity as indicated by providing more plant growth and nutrient uptake (N, P, K, Ca and Mg) (Puttaso, 2003). Bossard (2004) inferred calcined montmorillonite clay that best improved soil aeration, break up compaction and promotion stronger root growth. Hartmann *et al.* (2000) found that subsoiling had no effect on plant growth while bentonite application in slot technique allowed yield and biomass to increase 53 percent, rooting depth increased and bulk density decreased in slots. Furthermore, Waterstripe and Milarch (1998) came up with the optimum level of montmorillonite supplementation rate benefitial to spinach production of 100 g m^{-2}.