# CHAPTER II

# LITERATURE REVIEW

## 2.1 Soil fertility and organic fertilizer application

Soil is the uppermost surface of the earth, which has been transformed slowly by decomposition under the action of weather, vegetation and man. It gives support to the plants by providing a permeable layer for the roots; and is a kind of storehouse for plant nutrients and water. Soil fertility is the capacity of a soil to supply plant nutrients in adequate amounts to facilitate optimum growth and obtaining the yield potential of a crop. In the agricultural science, soil fertility which is fundamental to sustain agricultural productivity and plant nutrition; has played an important role during the 20th century in increasing crop yields. In the 21st century, importance of this field is still expanding due to the limitations of natural resources (land and water), sustainable agriculture and concern about environmental pollution (Fageria, 2007).

According to DOA in Sri Lanka, the genetic potential of any variety can be realized only when, crop management practices are optimized in the presence of favorable climate, edaphically and biotic environment (DOASL, 2006). Many soil properties determine fertility status of the soil. Main factors that determining soil fertility are: soil organic matter, texture, structure, depth, content of nutrients, storage capacity (adsorption capacity), soil reaction and the absence of toxic elements (e.g. free aluminium). Soil organic matter content; as one of the key parameters which influence soil fertility and productivity, consists with living organisms, dead plant and animal residues. It is the most chemically active portion of the soil. It functions as a reservoir for various essential elements, contributes to cation exchange capacity

(CEC), promotes good soil structure, buffers soil pH and promotes good air and water relations in plants (FADINAP, 2000). Application of these materials may also enhance microbial growth and nutrient turnover in soil (IRRI, 2003); and it has also been reported to reduce agricultural pollution and improve yield and quality compared to conventional practices (Dufault *et al*., 2008).

Agronomic evidences have indicated that organic fertilizers release nutrients more slowly than chemical fertilizers; and also found that long-term adverse effects of chemical fertilizers on soil properties and the environment can be ameliorated by using organic sources that match nutrient-release patterns with the crop demand (Pandey, 1999). According to Fageria (2007), increasing crop yield will be associated with rational use of chemical fertilization, increasing use of organic sources of nutrients, recycling of plant available nutrients and exploiting genetic potential of crop species or cultivars within species in efficient use of nutrients. In addition; Usman (2000) argued that organic materials alone could not completely substitute chemical fertilizers; they enhance crop yields by increasing the use efficiency when applied with chemical fertilizers. Therefore the use of organic manures available on-farm can return high yields and profit when combined with inorganic fertilizers, particularly on upland or poor lowland soils (IRRI, 2003).

## 2.2 Fertility improvement in paddy soils

Rice is very highly responsive to nitrogen (N) application. To achieve a yield of one ton per hectare, rice plants need 17 Kg elemental N, three Kg elemental phosphorus (P) and 17 Kg elemental potassium (K) (Philrice online). Responses to N application vary with soil type, landscape, crop duration and management conditions.

As a thumb rule to produce 20 Kg of rice, addition of one kilogram of N is needed. The N use efficiency in Sri Lanka is less than 30% due to high leaching and volatilization losses. With regards to K; rice is one of the crops which predominantly absorb K. Recently, additional K has been recommended if the targeted yields are high (more than 5 tons/ha); as sufficient K (above 1.5% in leaf dry matter) after flowering is necessary to facilitate carbohydrate translocation which enhances grain filling to give an increased 1000 grain weight (FADINAP, 2000). Furthermore, rice being an annual crop; removes a considerable amount of nutrients proportional to the yield obtained. About 40% of N, 30–35% of P, 80–85% of K, and 40–50% of sulphur (S) taken up by rice remains in straw and stubble at crop maturity.

Generally, rice soils in Sri Lanka are low in available P and exchangeable K. Soil organic carbon (C) depletion is inversely proportional to the amount of crop residue C incorporated into the soil. In tropical soils, precipitation, temperature and soil aeration express a strong effect on the quantity of organic materials input and the rate of organic matter decomposition in soil. Therefore it should be noted that increase of organic matter in soils; is a difficult task due to prevailing high temperature in many parts of the country. In this regard; seasonal applications of organic materials are necessary. Dufault *et al*. (2008) described that the use of organic fertilizer neither improved crop yields and quality nor reduce nitrate loss after a single season. Muna *et al*. (2007) were able to notice an improvement of C, N and calcium (Ca) content of soil, only after two years application of organic residues and manure. These findings are consistent with previous research reports, describes that more than a single of organic management is needed to improve soil properties and to achieve potential yields of newly introduced high yielding varieties. In addition, Listinger (1993) noticed that, fertilizer responsive varieties and shortages of manure had seriously depleted soil fertility; creating secondary pest problems that contributing to stagnating yield.

So it is advisable to combine the use of organic manures with the application of inorganic nutrient sources as needed. Therefore wherever possible, nutrient sources such as farm yard manure, straw, green manure and paddy husk charcoal should be used in combination with mineral fertilizers to provide part of rice crop's nutrient requirements and to sustain soil quality in the long run (Fairhurst *et al*., 2007). In addition, such technologies can also help to reduce negative environmental effects of using high level of chemical fertilizers.

### 2.3 Fertilizer recommendations for paddy production

More than 90% of paddy cultivars grown in Sri Lanka, is "New Improved Varieties" (NIV) with yield potentials over 10 tons/ha. These high yielding varieties refers to Bg, Bw, Ld and At varieties released respectively by Batalagoda, Bombuwala, Labuduwa and Ambalantota rice research institutes of the Department of Agriculture.

Typically in tropical regions of Asia, the potential yield is around 9-10 tons/ha in high yielding seasons and 6-8 tons/ha in low yielding seasons (Fairhurst *et al*., 2007). To achieve potential yields of these newly improved varieties, the DOA released a fertilizer recommendation in 2001. As the above yield levels couldn't be achieved with following chemical fertilizer recommendations alone; and possible with combined application of organic manure under favorable conditions, they recommended it as a package with organic fertilizers and it is known as "integrated nutrient management" in paddy production.

**2.4 Integrated Nutrient Management (INM)**

In general, integrated nutrient management is a long-term approach to effective maintenance of soil and crop productivity. Falling soil fertility of rice growing soils due to many reasons necessitates the use of INM to increase production. This can be defined as the maintenance or adjustment of soil fertility and plant nutrient supply at an optimum level, to sustain the desired crop productivity through optimization of the benefits from all possible sources of plant nutrients such as chemical fertilizers, green manure, bio-fertilizers, crop residues, legume crops, industrial waste, farm waste and organic manure in an integrated manner. The maintenance should be appropriated to each cropping system and farmer situation of plant nutrients within its ecological, social and economic possibilities (FAO, 1995). It will also produce more healthy plants which minimize the necessity of using pesticides and fungicides, which are harmful to the environment (FADINAP, 2000).

However in many areas, organic manure is not available in sufficient quantity to balance nutrient removal; and the use of organic manure is more costly than the application of equivalent amounts of nutrients as mineral fertilizers. Straw is the only major organic material available to most rice farmers.

## 2.5 Management of organic matter under Integrated Nutrient Management

### 2.5.1 Rice straw

Straw is always available on-farm, because it is an inevitable by-product of paddy production. Incorporation of stubble and straw into the soil returns most of the nutrients taken up by the crop, and helps to conserve soil nutrient reserves in the long term (Fairhurst *et al*., 2007). Even though the short-term effects on grain yield are often small (compared with straw removal or burning); long-term benefits are significant. Where mineral fertilizers are used and straw is incorporated, reserves of soil N, P and K are maintained or even increased. Straw is also an important source of micronutrients such as zinc; and the most important influence is on the cumulative silicon balance in rice.

Burning results in the loss of almost all the N content, P losses of about 25%, indirect potassium losses of 20% because of leaching, and S losses of 5–60%. Where S-free mineral fertilizers are used; straw may be an important source of S; and thus straw burning should not be practiced. In contrast, burning effectively transforms straw into a mineral K nutrient source and only a small amount of K is lost in the process. According to research findings, the effect of straw removal on long-term soil fertility is much greater for K than for P (Fairhurst *et al*., 2007). However as straw spreading and incorporation are labor-intensive; farmers consider burning to be more expedient. But efforts should be taken to promote recycling of straw in paddy cultivation.

Straw have mature tissues with high C : N ratio. As it takes longer times to decompose; direct application of rice straw will cause temporary immobilization of soil N. Therefore in order to get maximum benefits, farmers have to incorporate them into the soil at the rate of four to five tons/ha (total weight of rice straw of the previous crop), two or three weeks before land preparation or three or four weeks before planting of rice. They can be evenly placed on levies before land preparation. Impounding of water results imbibing and loose the tensile strength. After land preparation, these heaps can be distributed evenly on the levies and incorporated to the soil with the second ploughing. Spreading straw uniformly in the field will be useful to avoid creating "nutrient hot spots". Over 12 to 15% increment of yield has been observed through the application of this mechanism (FADINAP, 2000).

### 2.5.2 Paddy husk charcoal (Charred paddy husk)

Rice needs an adequate supply of silicon (Si) for healthy growth. As paddy husk is a good source rich in Si; it can be used in Si supplement in paddy cultivation. Not only for that, but also for some other beneficial effects such as buffering soil salinity, alkalinity, toxicity levels and control of soil born diseases. The DOA recommendation for the application of charred paddy husk to paddy cultivation is 625 Kg/ha. Farmers who used mineral fertilizers along with cow dung, green manure and paddy husk charcoal were able to gain 10 to 10.5 tons of paddy per hectare; and this yield could have been sustained through continuous application of those materials (FADINAP, 2000).

### 2.5.3 Farm yard manure (FYM)

Farm yard manure is an excellent source of plant nutrients, consists of materials collected from animal droppings, beddings and domestic sweep. The value of animal manures has been recognized since ancient times. It has been noticed that, animal wastes have more N than plant parts, and they decompose faster than them. The recommended rate for the application of cow dung and poultry manure in paddy cultivation is, five and three tons/ha respectively. They can be incorporated into the soil at the second ploughing. Comparatively, layer litter is more suitable than broiler litter as it is easier to decompose. It should be noted that not to apply poultry litter immediately before seeding or transplanting; as the ammonia gas released may increase the pH and may cause killing the plants.

It has been observed that supplementing straw recycling with cow dung at two tons per hectare has increased the yields up to 7 to 8.5 tons/ha, and this could have been sustained through continuous application of those fertilizers (FADINAP, 2000).

However the use of animal waste in paddy cultivation is very limited. Unlike for cash crops, the costs of transportation of animal manure are too high to permit their application in rice cultivation. In addition, sources of animal manure are expensive due to high demand by vegetable growers. Limited number of livestock owned by farmers, low availability and inadequate storage facilities are also can be considered as limitations for the inadequate utilization of farm yard manure. Adequate concentration on careful maintenance to minimize odor, nutrient losses and emissions is essentially needed for preventing it becoming a source of pollution.

### 2.5.4. Green manure

Many green manure legumes such as the fast-growing, short-duration and stem-nodulating sesbania (*Sesbania rostrata*) can accumulate N rapidly (80–100 Kg N/ha in 45–60 days of growth). Most of the N (about 80%) is derived from biological N fixation. Green manures decompose rapidly when incorporated into the soil and may provide a substitute for fertilizer N applications, especially during vegetative growth. However; the variety, age, part of the plant and moisture content of the soil determine the quickness of decomposition. Younger leaves and tender stems which have more water, N and less other minerals; decompose faster than mature leaves and stems. Mature parts; which have more cellulose containing materials, take a longer time to decompose (FADINAP, 2000).

Green manure can be applied to the field in two ways at the rate of two to three tons/ha at the second ploughing. The first way is after growing in the field and ploughing at flowering due to high N concentration. *Crotalaria juncea* (Sun hemp) and *Sesbania rostrata* are good examples for that method. The second way of application is to apply leaves and tender stems lopped from trees to soil after ploughing. *Gliricidia sepium*, *Ipil ipil* and *Tithonia diversifolia* (wild sunflower) can be considered as good examples under this category. They can be grown in live fences, major bunds and hedge rows.

Green manuring has also been noticed, as an effective way in accelerating the reclamation of saline soils (Fairhurst *et al*., 2007) and also as a successive measure for weed management.

However, seed shortages due to the absence of proper arrangements in synthetic seed multiplication programmes, low seed yield, laborious seed picking and poor germination are the limiting factors for large scale adoption of most types of green manure application practices. Poor land, labor and moisture availability also adversely affect to such seed production programmes.

### 2.5.5 Bio fertilizers

In addition, Cisse and Vlek (2003) identified an Azolla intercrop; which can be used to reduce N losses in flooded rice fertilized with urea, by immobilizing urea-N during periods of potentially high N-loss. Grain yield and N recovery were positively influenced by this free-floating water fern; by more than doubling the grain yield and N uptake as compared to the split application of N. Thus, Azolla contributes to the conservation of N in the system, particularly of the urea application early in the season. Loss of N from the system amounted to no more than 15%. Although the early-applicated N directly recovered by the rice plant was low (20%); 2/3 of the N captured by Azolla following the first urea application was released to the system by the time of rice harvest, over 40% of which was available to the rice plant. Azolla thus appears to act as a good source of slow release biofertilizer.

## 2.6 Limitations and challenges to organic fertilizer application

Having so many advantages in using organic fertilizers, some limitations also can be found such as; difficulties to apply as it can be bulky with high handling and transportation costs, low availability, has to be applied at the beginning of the crop, can have unpleasant odor making it undesirable for farmers and for the others, may have high costs per unit of nutrients and sometimes more expensive than inorganic fertilizers. Time gap between two crops may also limit the use of organic fertilizers. Mostly they require land, labor and other inputs for their production and application. As a result of that, the use of organic fertilizers such as compost that require high labor intensity will be limited in labor scarce societies (Pandey, 1999). These considerations suggest that; organic manure should be generated in the field itself or in its near vicinity, if the practice is to be accepted by farmers (Wijewardena, 2006).

There is also a limited storage and retail marketing facilities for organic manures. Therefore it is not easily accessible for most of farmers. Even though the market for chemical fertilizers is controlled as a standard product, selling of organic manure is done without any standards.

Beliefs of farmers may also affect adversely to the application of organic fertilizers in paddy cultivation. Some believe that organic manures may carry pests, pathogens and weed seeds and propagate them in the current or following crops. Even though the farmers expect immediate and quick economic benefits with INM practices; the slow, almost unseen nature of soil organic matter dynamics may takes several years to begin to improve soil organic matter concentrations and crop yields. However, this hinders and restricts the adoption of INM at farm level.

However, increased use of fertilizer is considered to be environment pollutants. Nitrogen fertilizers, when used in excess can be leached or washed through erosion into waterways and reservoirs; and have been reported to eutrophication. Therefore efficient and cost-effective INM strategies should aim to maximize crop uptake of nutrients from fertilizers and soil indigenous sources. Better crop management practices can make full use of nutrients available in the form of straw, other crop residues, animal manures and mineral fertilizers as required overcoming specific nutrient limitations. The risk of crop failure can be minimized by selecting realistic and economic yield targets, practicing the efficient use of fertilizers, balanced nutrients and maximize revenue by considering the cost of inputs including labor, organic manure and inorganic fertilizers. Increase in technical efficiency requires substitution of inputs by knowledge. Instead of just applying more nutrients, technical efficiency can match the supply of nutrients with plant demand; and it will maximize the uptake. Such matching would require knowledge about the crop status and the nutrient supplying capacity of the soil at different points in time throughout the crop growth cycle. Therefore integrated soil nutrient management requires greater management skills than those required for the application of inorganic fertilizers alone or organic fertilizers alone; since it requires combination of two inputs in correct proportions. Precision in the depth of application is based on specific factors such as soil or plant tests and additional time investment to learn, acquire and use of such knowledge-intensive technologies (Fairhurst *et al*., 2007).

Therefore, introduction of new technologies are not enough for better performance; encouragement of farmers to adopt those technologies also is a must.

## 2.7 Technology adoption process

Among many other factors that contribute to the growth in agricultural productivity; technology is the most important. Technologies play an important role in economic development. The decision to use a new technology or practice by economic units in a regular basis is commonly refers to adoption.

The adoption process of a technology is a mental process through which an individual passes from first hearing about an innovation to final adoption. This process is conceptualized in five stages or steps: awareness, interest, evaluation, trial and adoption. At awareness stage, the individual is exposed to the innovation but lacks complete information about it. He or she then becomes interested in the innovation and seeks information about it at the interest stage. At the evaluation stage the individual mentally applies the innovation to his or her present and anticipated future situations, and then decides whether or not to try it. The individual uses the innovation on a small scale in order to determine its utility in his own situation at the trial stage. At the adoption stage they decide to continue the full use of the innovation (Rogers, 1962).

In the adoption process, personal communications involve a direct face-to-face exchange between the communicator and communicatee. Cosmopolite information sources are most important at the awareness stage, and localize information sources are most important at the evaluation stage (Rogers, 1962). Farmers' decision to adopt a technology depends on many factors, such as physical availability of inputs, farmers' purchasing capacity, cost of acquiring information and learning the way how to use the technology. They benefit from the adoption of new technology through opportunities to lower the production costs, either by increasing outputs from the same inputs or by maintaining the same output from reduced inputs.

Therefore the public sector can play an important role in this, by manipulating the price policy and in translating the latent demand into actual demand through institutional interventions such as the provision of inputs, credit, extension and education (Pandey, 1999).

Based on this background, adequate understanding of technology adoption process and its diffusion will be useful for designing effective agricultural research and extension programmes.

## 2.8 Role of extension in the adoption process

Extension workers need to understand how to integrate the latest research results into cropping systems and area specific recommendations. So the extension programmes should be strengthened through developing technology packages that address farmers' resource constraints rather than wholesale recommendations on fertilizer dosages and other new technology options (Wubeneh and Sanders, 2006). If government encourage farmers to participate in extension services and provide them with opportunity to get the experience of technology; then it could be adopted by farmers (Zhou *et al*., 2008), and it will help to improve their performances and raise profitability. But mostly in extension, farmers are used to implement the others' decisions in their fields. This is happened by giving instructions of research or extension officers through mass media, posters, flip charts or model demonstrations where the farmer is effectively serving as a laborer. But these communication approaches does not educate farmers. As education is the most important thing that an extension programme can do; within the educational approach communication can take place at the field level, dealing with field issues in dialogue with learners. It will be better if mechanisms like farmer field schools can be used to achieve this objective of helping farmers to master and apply their field management skills to implement his or her own decisions in their field (FAO, 2000).

## 2.9 Factors influencing technology adoption

Technology adoption process is expected to be affected by several factors. There is a wide body of literature regarding the determinants of adoption of technical innovations in agriculture. A number of adoption studies report that technology adoption is linked to farmer resource endowment in terms of human, physical and financial capital, risk preferences, location factors and characteristics of the technology itself (Simtowe, 2006). Characteristics of the household head and the household, type of landownership and institutional contribution towards the technology can be considered as more important factors that influence the adoption process.

### 2.9.1 Characteristics of the household head

Age, education and perceptions are important characteristics of the household head that affects technology adoption. Yamota and Tan-Cruz (2007) gives evidence to the importance of age on technology adoption. Simtowe (2006) found a negative influence of age on technology adoption in his study; implying that the older farmers have a tendency to stick to their old production techniques and they are usually unwilling to accept change. In addition, young people are associated with higher risk taking behavior than the elderly. But Damisa and Igonoh (2007) have argued that the older farmers are more likely to try new technologies as they are rich with more resources than younger farmers. Education (years of schooling) was also considered as a major determinant of technology adoption, and found to be having a complex impact on it. Yamota and Tan-Cruz (2007), exhibited a positive influence of education and also farmers' valuation towards the technology on its adoption. Nkamleu (1999) also found a positive relationship between education and the adoption of integrated soil nutrient management. But Zhou *et al*., (2008) found a complex impact of education on technology adoption in their study. They indicated farmers' membership in an extension service, as the most important driving factor for the adoption of a water saving technology in China.

### 2.9.2 Characteristics of the household

Farm size owned by the household, family size and family income can be considered as important household characteristics that significantly affect to the technology adoption process. The effect of farm size and family size is not clear on adoption literature as they can influence the adoption in both directions (Kosura *et al*., 2001). However, Zhou *et al*., (2008) identified farm size having a significant positive effect on technology adoption. Households with large farms showed higher adoption possibilities than small farms. Same results were observed by Sarwar *et al*., (2007), confirming that with increased landholding, farmers have better choices to experiment with new technologies as compared to resource poor farmers. Some recent studies have looked at the specific aspects of the influence of family size on technology adoption. Namara *et al*., (2003) and Nkamleu (1999) found a significant positive influence of family size on technology adoption in their studies. Results of Yamota and Tan-Cruz (2007) were in accordance with this and they found an increase likelihood of the adoption of organic farming with more number of family members engaged in farming practices. Same results were found by IFAD (2003); explaining that with more availability of family labor, households will find it easier to face the higher demand for labor associated with organic methods of production. With reference to family income; even though Yamota and Tan-Cruz (2007) found a negative influence of it on technology adoption; Namara *et al*., (2003) found a positive relationship of family income with the system of rice intensification (SRI) technology adoption. They have argued that the rich are more educated and more inclined to experiment with new methods and; higher the capital availability within farm households, the greater the likelihood of farmers using soil nutrient management practices. Sanni and Doppler (2007) found a significant influence of landownership on fertilizer use intensity in their study. But the effect of the type of land ownership on technology adoption is more controversial.

### 2.9.3 Technical / Institutional characteristics

Trainings and extension contacts can be considered as major institutional factors that affect technology adoption; and were hypothesized to positively influence the adoption, as these supporting services facilitate the uptake of technologies. It was confirmed by the results of Namara *et al*., (2003) with having positive influence of training programmes on SRI technology adoption. Yamota and Tan-Cruz (2007) also indicated the number of seminars or trainings attended by a farmer as a significant factor that affects the rate of adoption. Contacts with extension was found to be positively and significantly related to farmers' adoption in integrated soil nutrient management (Nkamleu, 2007), and also to the adoption of improved maize varieties in Nepal (Ransom *et al*., 2003).

## 2.10 Methodologies used for studying technology adoption

Models used to examine the relationship between the adoption and determinants of adoption involved a mixed set of qualitative and quantitative analyses. To measure the outcome of such discrete output, a variety of multivariate statistical techniques can be used to predict a binary dependent variable from a set of independent variables. Multiple regression and Discriminant analysis are two techniques for this purpose. However, these techniques pose difficulties when the dependent variables have only two values, 1 if the event occurs and 0 if it does not.

The Binary Logit Regression is a type of regression where the dependent variable is converted into a dichotomous binary variable coded 0 and 1. Therefore this model (BLRM) is considered appropriate in such a situation. It requires far fewer assumptions than the other two mentioned above (Hosmer and Lemeshow, 1989). It is also called Logit, which is applicable to a broader range of research situations, and is able to predict the presence or absence of a characteristic or outcome based on the values of a set of predictor variables.

Many past studies have demonstrated that Logit model can be applied to capture the influence of socioeconomic variables on farmers' adoption decisions (Zhou *et al*., 2008, Sarwar *et al*., 2007, Nkamleu and Manyong, 2005, Namara *et al*., 2003). In this model farmers are assumed to make adoption decisions based upon an objective of utility maximization. It is similar to a non-linear regression model but is suited to models where the dependent variable is dichotomous. There is flexibility in the model where independent variables can be interval level or categorical; they should be dummy or indicator.