Comparing economic and environmental sustainability of intensive and organic agricultural systems to support land use policy formulation aimed at reducing agrarian distress in Karnataka State, India



Master Thesis

By

Pratik Nigam Shah

Plant Production Systems

Wageningen University and Research Centre, November 2009

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Pratik Nigam Shah

November 2009

Registration number: 870413759020

Msc program: Masters Organic Agriculture

Supervisor:

- Dr. Pytrik Reidsma – Plant Production Systems Group, Wageningen University and Research
- Ir. Joost Wolf – Plant Production Systems Group, Wageningen University and Research

Examiner

- Dr. Ir. Martin K. van Ittersum- Plant Production Systems Group, Wageningen University and Research

Table of Contents

Abstract

Karnataka state is a state of India with diverse agro-climatic zones. In 2001 it had a population of 53 million and 66% of population habitants living in villages. Agriculture is still major occupation in the rural areas of Karnataka and more than 90% of rural people are dependent on agriculture and agro-industries. However irregular rainfall patterns, pest attacks and poor nutrient management are resulting more frequently in crop failures. This has resulted in agrarian distress as with crop failures, farmers are unable to repay the loans. The government of Karnataka introduced Karnataka state policy of organic farming to decrease agrarian distress.

In order to asses the impacts of this policy on agriculture, economic and ecological sustainability were compared among organic agriculture and conventional agriculture in two districts, Mysore and Chitradurga. Input and output relationships of agriculture were quantified by a technical coefficient generator (TechnoGIN). Four scenarios were selected for comparing the organic and conventional agriculture: 1) Difference between organic agriculture and conventional agriculture in current situation; 2) Projecting changes in future for the year 2015; 3) Different impacts of crop failure on debts of farmers; 4) Optimal nutrient management in conventional and organic agriculture. The data used were based on own field surveys and farm surveys by ATREE (NGO), agricultural scientist expertise and literature review. Economic indicators included gross income, fertilizer costs and net profit and the ecological indicators included nitrogen losses, nitrogen surpluses, water requirements and the biocide index. Results shows that different crop rotations vary in profitability while comparing organic and conventional agriculture, but the risk of getting in debt are more in conventional than organic even while projecting the changes for the year 2015. The nitrogen losses and surpluses are more in conventional than organic agriculture but there is problem of nitrogen mining in organic farming. In the end we can conclude that due to low costs of inputs in organic compared to conventional agriculture, Karnataka state policy of organic farming can reduce distress in the selected villages in Mysore and Chitradurga due to low risk of getting debts. However, considering the major crops, organic farming is less of an option in Mysore, as productivity and hence profitability is lower compared to conventional farming.

Declaration

Here I declare under oath that I accomplished this work independently and without outside help; in the document all consulted sources are mentioned as such and I have not made use of any other resource.

November 2009

Pratik Nigam Shah.

Acknowledgements

This study was carried out under Karnataka, India case study in LUPIS (Land Use Policies and Sustainable Development in Developing Countries). It is an EU funded project run by 16 institutes in 13 countries.

First of all, I am very grateful to have my supervisor, Dr. Pytrik Reidsma Research scientist from Plant Production Systems chair-group of Wageningen University. It was her communication and guidance that inspired me to choose my thesis topic. I really appreciate her kind assistance, critical comments and her productive advice throughout the thesis. She is very supportive and inspiring for me. She never hesitates to provide me help at any time.

Secondly, I would like to express my sincere appreciation to my co-supervisor Ir. Joost Wolf from same group Plant Production Systems, Wageningen University. It was his technical guidance that solved my problems in TechnoGIN. He is very supportive and gives explicit guidance.

I would also like to thank Dr. Ir. Martin K. van Ittersum from Plant Production Systems. It was through Pytrik and him that sponsorship my trip to India was possible. His guidance at early stages of my thesis was really helpful.

The assistance of data collection and warm hospitality provided by Dr Seema Purshothaman and her colleagues Sheetal Patil, Ierene Francis from ATREE (Ngo), India, are gratefully acknowledge. I am thankful for their numerous support and useful suggestions.

Special thanks are given to Indian fellows in Wageningen. Also International friends of my masters program organic agriculture, for their heartening companies.

Lastly I would like to thank my family for the financial support and warm encouragement during my stay in Netherlands.

1. Introduction

1.1 Land Use Policies and Sustainable Development

To enhance sustainable development in developing countries, the Land Use Policies and Sustainable Development in Developing Countries (LUPIS) project was initiated (www.lupis.eu). In countries such as India and China, economic growth in the agricultural sector lags behind growth in industry and services, creating an ever widening rural-urban income gap. Developments in the industrial sectors or any non-agricultural sector offer new opportunities of employment, causing urban development and migration of farmers from rural areas to urban areas. Due to ever increasing urban population, the poverty levels are growing and food security is deteriorating. Conversion of agriculture and forest areas to industries and real estate are uncontrolled and besides the earlier mentioned issues this also leads to loss of biodiversity. In order to address these fundamental issues the LUPIS project is developed. It will investigate the linkage of land use policy to sustainable development in the specific context of a range of developing countries. It will develop and use suitable integrated assessment tools to assess impacts of land use policy on sustainable development. India is one of the selected developing countries and the Indian partner in this project is Ashok Trust for Research in Ecology and the Environment (ATREE).

1.2 India and agriculture

India's economy has been one of the stars of the global economy in recent years, and has seen a decade of 7% growth per year (OECD, 2007). Developments in industrial and service sectors are the main causes of economic progression in these recent years. Government regulation has been eased significantly or is less burdensome to the industrial sector which is one of reasons for having rapid developments. Areas such as communication, insurance, asset management and information technology have grown rapidly. Due to favourable liberalisation in industrial policy, growth in private sectors has been effective. Thus, further reforms in these areas was complemented with measures to improve infrastructure, education and basic services in big cities of India, that have increase the potential growth outside of agriculture and rural areas and thus boost better paid employment than agriculture. Now this growth in industrial sector is improving standard living conditions and lowering poverty and unemployment. But still 60% of India's 1.1 billion population is living with agriculture and its allied activities. This sector has major challenges including droughts, floods, urban migration, poverty alleviation and rural unemployment. Agriculture accounts for about 17-19% of Indian economy in terms of GDP. The annual growth of agriculture and its allied activities was on average 4.46% in the last 4 years, which is lower than other sectors such as industries, mining, energy and supply, service sectors (Purushothaman and Kashyap, 2008).

The Rockefeller foundation research in high yielding varieties of seeds, their introduction after 1965 and increased use of fertilizers and irrigation are known collectively as the Green revolution. These provided the increase in production needed to make India self-sufficient in food grains, thus improving agriculture in India. India is one of the largest producers of all agricultural commodities and dairy products in the world. Despite all the natural advantages, India's productivity of food grains per hectare is no more than three fourths of the world average and less than half of that in agriculturally advanced countries. Per capita food grain availability, even after the Green revolution, has been less than two thirds of the world average (Shanwad et al., 2004). In-spite of the Green revolution, since 1985 there is a decline in agricultural growth and increase in rural poverty (Singh, 1997, Kumar and Pasricha, 1999). These are due to long persisting government indifference towards the farming sector, which includes long persisting adverse terms of trade policies for agriculturists, in addition to the mismanagement of natural resources. The hybrid seeds in India had increased the production per hectare during the green revolution in terms of food-grains, fibres, etc., but those varieties had also cons: they increased 1) the fertilizer, pesticides, irrigation application, and 2) a higher nutrient removal from soils (Shiva, 1989). Clearly, expansion in fertilizers application continues to fall short of nutrient removal, resulting in depletion of soil fertility and negative nutrient balances. This situation cannot go on forever and is at stake with a principle of sustainable agriculture.

1.3 Agriculture related problems and policies

Agrarian distress is one of the major problems in India. Numbers of farmers committing suicides are increasing every year. The suicides are a direct result of the stress caused to the farmers by the pressure to pay back various money debts. The lack of money at the end of a year shows that there is not enough profit from the farming. The reports of the Yashada organization, an autonomous administrative farmer training institute which is working on farmer suicides, funded by Government of India and Maharashtra, says that there is no safety net for farmers to protect them from usurious credit suppliers exposure, to unbearable price fluctuation and spurious input for farming (seeds, fertilizers, pesticides). Government efforts to educate farmers in better and more productive techniques are still inadequate (Anonymous, 2006a).

The Green revolution is also associated with negative ecological/environmental consequences. In India, about 182 million ha of the country's total geographical area of 328.7 million ha is affected by land degradation. Of this, 141.3 million ha are due to water erosion, 11.50 million ha due to wind erosion and 12.63 and 13.24 million due to water logging and chemical degradation. Besides this, the forest and cultivable land is shrinking, which became the biggest threat to habitat of animals, birds and useful insects (Shiva, 1989).

Despite the steady decline in its share of the GDP, considering the workforce the agricultural sector still remains the largest economic sector in the country. Low and volatile growth rates and the recent escalation of the agrarian crisis in several parts of the Indian countryside are a threat not only to national food security, but also to economic well being of the nation as a whole. Many policies were implemented by the Indian government in the field of agriculture and industries, with the intention of having balanced growth of rural and urban areas of the country (Purushothaman and Kashyap, 2008).

Policies such as high subsidies on fertilizers such as urea, seeds and pesticides had no effect on the farmer's benefits. The high yielding varieties used in agriculture were not high yielding or highly responsive unless proper inputs such as fertilizers, irrigation and pesticides were applied to the particular crops. The costs of those inputs are not affordable for the small and marginal land holding farmers. Intensification and mechanization are therefore limited for these smallholders. Farmers argued that in the absence of the fertilizer and water, the new seeds perform worse than indigenous varieties (Shiva, 1989). The gain in output is insignificant compared to the increase in inputs.

Due to promotion of new seeds, the availability of indigenous varieties on the market is currently very low. Farmers have to store their own seeds for the next cultivation in the next year. This situation is the current reality, while diversity was one of the important principles of traditional agriculture in India. India had large genetic diversity of rice. The Green revolution package has reduced genetic diversity at two levels. Firstly, it replaced mixtures and rotations of crops like wheat, maize, millets, pulses, and oilseeds with monocultures of wheat and rice. Second, the introduced wheat and rice varieties came from a very narrow genetic base (Shiva, 1989). Poor market infrastructures such as improper storage facilities, poor transportation, illiteracy, fluctuation of market price despite of having minimum support prices to agricultural crops are still huge problems for Indian farmers.

The Minimum Support Price Policy should reduce distress of farmers, but does not fully achieve its objectives. The government fixes the minimum support prices for selected agricultural products every year. These prices are fixed with the help of the Commission of Agriculture for Costs and Prices (CACP). The government fixes the prices, taking into account that farmers get remunerative prices, so they are able to invest back in agriculture and feed their families properly.

An important challenge for India’s development is to ensure that small scale farmers participate in and contribute to agricultural and rural growth (Mundy, 2006). The land productivity of small farms have always been higher than large farms and the transaction cost of smaller farms are lower than for larger farms as small farmers have production for their own home consumption or for local market. But the problem arises is farm income to run their own livelihoods is not enough.

The following Table 1.1 presents the average farmer’s input cost for the production of food-grains in a medium fertile soil and it also demonstrates the net income a farmer gains in current farming practices. This is input and output for only one season. A small farmer is a farmer having less than one hectare and a marginal farmer has 1-2 hectare. The cost of small farmers are more than larger farmers but gross income is higher than marginal due to higher productivity and a tendency to sell to local markets instead to large ones that decrease transaction cost.

Table 1.1 Average economic analysis of small and marginal farmers (Singh and Joshi, 2003).

Cost in INR/farm	Small	Marginal
Depreciation on fixed capital	202	116
Seed	970	987
Fertilizers and Farm Yard Manure (FYM)	2164	1813
Plant protection measures	308	210
Irrigation charges	1234	1122
Hired human labour	821	840
Tractor	2283	2872
Bullock	171	248
Combine harvester	0	0
Miscellaneous	152	146
Interest on working capital	607	528
Rent paid for leased-in-land	11281	9750
Imputed value of family labour	5404	5278
Total Cost	25597	23910
Income	49311	47206
Gross return	23714	23296

1.4 Organic farming

The Indian Council of Agriculture (ICAR) is an autonomous organization under the Department of Agricultural Research and Education, Ministry of Agriculture, Government of India. With over 90 ICAR institutes and 45 agricultural universities spread across the country this is one of largest national agricultural systems in the world. It has created a network of over 561 Krishi Vigyan Kendras (KVK) i.e. Agriculture Information Centres, aiming at assessment, refinement and demonstrations of technology / products in the rural districts of the country. This is one of the biggest modes of dissemination of the technology and knowledge transfer to millions of the rural people of the India. There are many projects such as All India Coordinated Research Project (AICRP), National Agriculture Innovation Project (NAIP), National Research Centre for Citrus, Soil Survey bureau and Land Use Planning which are carried out all over India under this institution which aims for the development of Agricultural and Rural Sectors of India. One of the projects is in the Organic Agriculture sector. The National Organic Program is a project which is carried throughout India.

Although agricultural production has continued to increase, the productivity rate per unit area has started to decline. Increase in chemical usage has not inevitably increase the production but at same rate it increased the farm cost and poor yields in arable crops fails to repay loans and lead to high debt, which is one main reason for the huge agrarian distress among the farmers of India. The entire agricultural community is trying to find out an alternative sustainable farming system, which is ecologically sound, economically and socially acceptable. In Europe, there is a rising demand for organic products, especially for organic cotton, tea and spices. These are reasons for farmers to convert into organic farmers, which are well supported by the Government of India.

Organic farming has been practiced in India since thousand of years. The great Indian civilization thrived on organic farming and was one of the most prosperous countries in the world. In traditional India, the entire agriculture was practiced using organic techniques, where the fertilizers and pesticides were obtained from plant and animal products. The cows were not only used for milk production, but also to provide bullocks for farming and dung which was used as fertilizer (Mahapatra et al., 2009).

Land use policy needs to be changed to tackle the ecological, social, economic problems in agriculture in India. The policy regimes and strategies are generally different, based on the issues of primary focus in each state and the regional characteristics, having various degrees of success. Introduction of Organic Agriculture in Karnataka is one of the policies. Karnataka State Policy on Organic Farming (KSPoOF) is a policy that has the potential to reduce debts of farmers and promote sustainable development. Therefore, it is the main focus for policy analysis in the LUPIS project. Before this state policy, the Government of India already launched a National Programme for Organic Production (NPOP) aiming at the same direction, and in 2000 standards and accreditation criteria and a National Organic Logo – “India Organic” has also been created.

1.5 Case study in Karnataka

Karnataka is a state in the southern part of India (Fig. 1.1). The state is bordered by the Arabian Sea to the west and is adjoined with 5 other states of the country. The state is the 8th largest state in India area-wise and the 9th largest population wise (Census 2001). It is characterized by high economic growth; from 1994 to 2004 the state observed approximately a 11% rise in per capita GDP, but agricultural share in the states GDP has decreased from 33% in 1993 to 15% in 2003 (Purushothaman and Kashyap, 2008). However, 66% of the population still depends on agriculture and agriculture is the main land use. Small and marginal farmers comprise nearly 75% of the total number of holding and their landholding size ranges from 0.5 to 1.5 ha.

Fig 1.1 Political map of India, with Karnataka in red.

The policies introduced in India mentioned above were also introduced in Karnataka state to boost the agricultural sector and to stimulate commercial diversification. But these policies did not improve livelihoods of most farmers. The reason behind this negative bias was the lack of effective implementation of the policies at different state levels and corrupted political leaders. Besides this, other factors like irregular rainfall patterns, pest attacks, poor nutrient management in soil resulted into crop failures. Consequently, farmers fall into debt as they fail to repay the loans mainly of non-institutional organizations. These loans were taken for buying large amounts of inputs such as seeds, fertilizer, irrigation facilities, pesticides and animals and transporting cost. The debts eventually cause them social and economic distress. The most important and widespread social symptom of distress in Karnataka's agricultural sector is the tragedy of farmers' suicides (Table 1.2).

Due to this incidence, Karnataka state government took the step of introducing the policy of Organic farming in March 2004 as alternative to current conventional farming. The policy is aimed at sustainability of agriculture in the state, as it requires less financial and external inputs and can increase employment at agricultural farms in rural areas. The main objectives are to reduce debt, improve soil productivity, increase water use efficiency, food security and mitigation to drought in small farms. As per policy recommendation, each district will have one organic village or site (100 ha) as a Model Organic Farm. Responsibility of popularizing Organic farming among the farming community was given to several NGOs in the state. Nodal departments, Nodal officers, Site officers and sites were selected based on the predominance of several activities in each district (Bezlepkina et al., 2009)

Table 1.2 Farmers' suicide incidence taken place in Chitradurga and Mysore, 2 districts in Karnataka, between 1 April 2003 and 1 January 2007.

Districts			2003-04	2004-05	2005-06	2006-07	Total
Chitradurga			55	19	8	17	99
Mysore			18	1	0	0	19
Source: Statistics from the Department of Agriculture							

1.6 Thesis objectives

For feasibility of this thesis, considering the period of work and geographical coverage, it was decided to choose two districts out of the five districts of Karnataka selected for the LUPIS project. Karnataka is characterized by diversity in its agro-climatic zones. All the selected five districts (Fig. 1.2) differ in agro-ecological conditions and cropping patterns; but only four of them are facing agrarian distress. In this thesis two district are focused having different climatic zones 1) Chitradurga (Central dry Zone) and 2) Mysore (Southern transition zone). The reasons behind selecting these two districts are not only the diverse agro-climatic condition – Chitradurga is a very dry area and receives average rainfall of 573 mm, while Mysore receives an average rainfall of 744 mm –, but also because the reasons behind the farmer distress are different in both districts. The problems linked with Chitradurga district are major pest and disease attacks in the cropping season and the problem in Mysore is mainly wildlife destroying the crops. The two villages of each district selected for the study are 1) Hiriyur village in Chitradurga district and 2) Mysore village in Mysore district. Data have been collected in 2006 and 2009 for both organic and inorganic farms located in these villages.

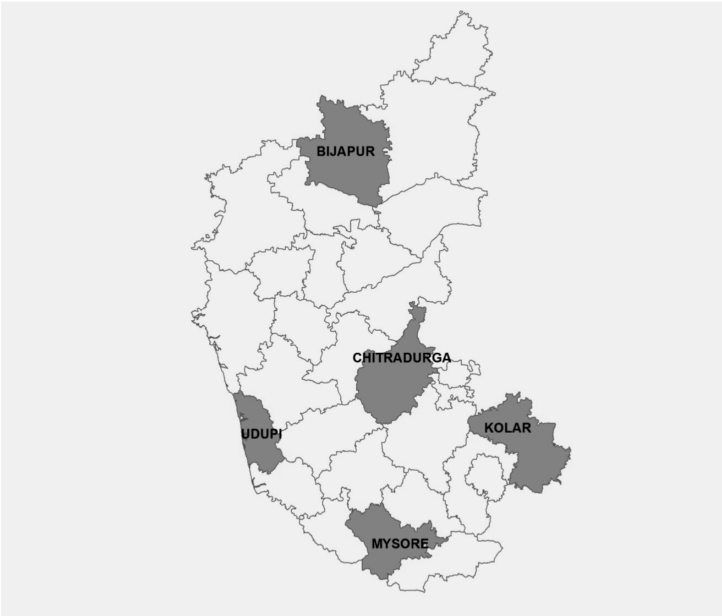


Fig 1.2 Political map of Karnataka.

The main aim of my study in this thesis is to compare the economic and environmental sustainability of intensive conventional agricultural activities with organic agricultural activities in the current situation in the same villages; and also between two different districts. The effect of organic farming will be different in different villages, as soil, climate, crops and inputs are different in both villages. The crop rotations and possible alternatives for both organic and inorganic activities will be assessed in the current situation 2008. The same crop rotations will also be assessed for the future year 2015. For 2015, data assumptions can be made on changing the crop yields, nutrient recovery percentage, market output prices, input costs, labour costs based on literature, regression analysis using previous data and expert knowledge. The tool that will be used is the technical coefficient generator TechnoGIN, which will be further explained in the Methodology Chapter.

The following are the sub-questions of the research:

1. What are the differences between intensive conventional farming and organic farming activities in terms of economic (i.e. gross income, costs, net profit) and ecological (i.e. water use, nutrient loss, nutrient surplus, biocide index) indicators in Chitradurga (Central Dry Zone) and in Mysore (Southern Transition Zone) in the current situation?

2. How may economic and ecological indicators for conventional and organic farming activities in Chitradurga and Mysore change for projection for 2015?

3. What are the main differences between these two regions, having different crop rotations and climatic conditions, in the current situation and in 2015?

4. How do economic and ecological indicators change for 2008 and 2015 in both districts when simulating an extreme event, such as pest attacks or droughts?

5. How can conventional and organic farmers improve their nutrient management to avoid positive or negative nutrient balances?

6. Which recommendations can be given to farmers and policy makers, based on the average performance of the conventional and organic agricultural activities and the impacts of extreme events causing distress?

2. Methodology

2.1 Model Structure

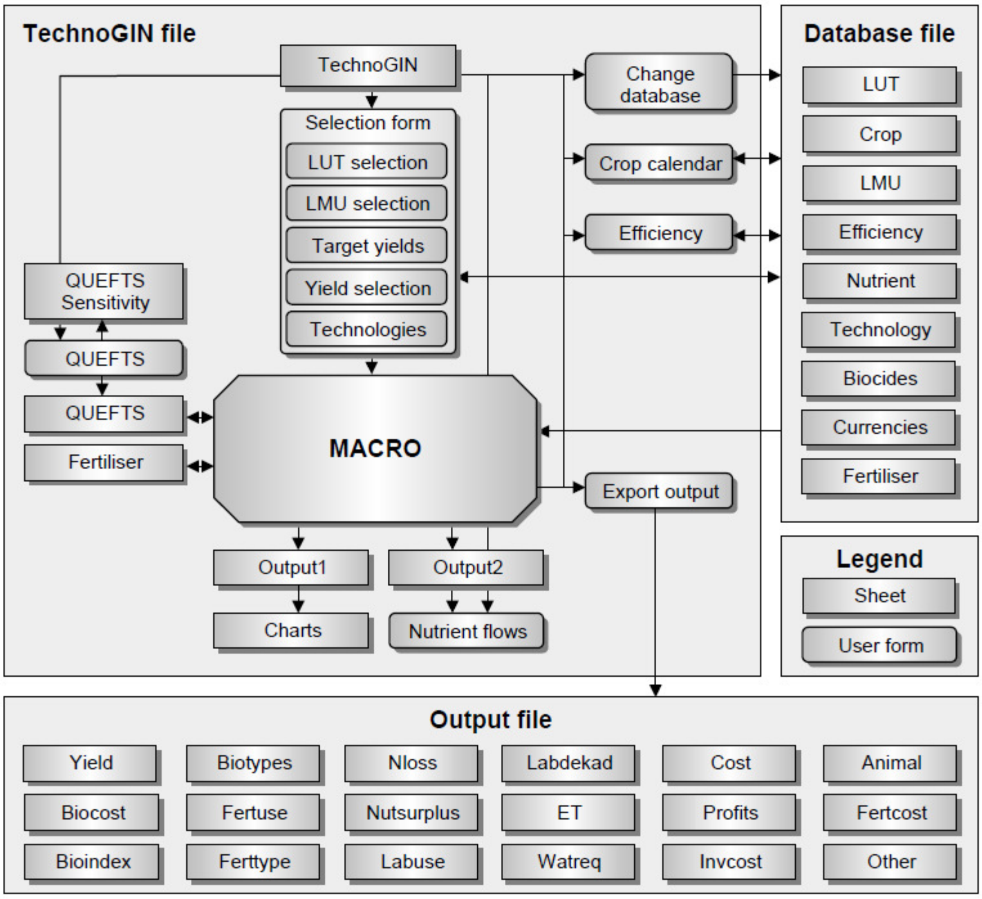
In order to compare the economic and ecological sustainability of conventional and organic agricultural activities, we are in need of an input-output model which describes inputs and outputs of land use systems. A land use system is defined by the crop rotation and the production technique in a particular land unit. The production technique consists of agronomic inputs such as seeds, fertilizers, labour and animals to realize a target production level (Van Ittersum & Rabbinge, 1997). The land unit is the area of the land and its physical environment such as soil, climate which may be homogenous within a region and heterogeneous between two different regions.

A technical coefficient generator (TCG) is a tool for creating an input and output matrix for all relevant combinations of land management units, land use types and production techniques that form part of a (regional) land use modelling framework (Ponsioen et al, 2003). TechnoGIN is a TCG developed for South-East Asia and has been applied in several case studies (Ponsioen et al., 2006). This technical coefficient generator calculates the technical coefficients such as monthly water and labour requirements, nitrogen, phosphorous and potassium fertiliser requirements, nitrogen losses by leaching and by gas, nutrient surplus in the soil, biocide index, different costs in the production of crops, and returns of crops in different rotations.

The calculations are done based on combinations of land use types and land management units. A land use type is a crop rotation, in Karnataka consisting of crops like onion, rice or sugarcane in the kharif or wet season; maize or ragi in the rabi or winter season; and sesame in the summer season. A land management unit considers the physical environment in which production takes place, including soil and climate conditions of the region. Target yields are defined per crop and production technique, with user defined input efficiency.

Programming of TechnoGIN is done in Excel files, including macros in Visual Basic. The current activities in the model are based on a farm survey and data from other sources such as literature, expert knowledge and government statistics. The nutrient balances are calculated based on target yields which are yields observed in 2008, fertilizer applications according to data, crop nutrient uptake and soil supplies. For alternative activities aiming at a zero nutrient balance (used for scenarios in 2015), nutrient recommendations (i.e. fertilizer applications) are estimated based on target yield levels, crop nutrient uptake, nutrient efficiencies and soil supplies. Nutrient use is optimized and recommended by using the model QUEFTS (Quantitative Evaluation of the Fertility of Tropical Soils), integrated in TechnoGIN, and based on the work of Janssen et al. (1990), Smaling & Janssen (1993) and Witt et al. (1999). The QUEFTS version in Techno GIN is based on Witt et al. (1999) and uses the Solver optimisation module in Microsoft Excel to estimate nutrient uptake at a target using maximum dilution and maximum accumulation of nitrogen, phosphorous and potassium (kg harvestable product/kg N, P and K, respectively) as constraints. The Solver optimisation module is also used to select an optimal mix of fertilizer types for supplying the nutrients as mentioned in fertilizer gifts bases on data or as estimated by QUEFTS.

Fig 2.1 Model structure of TechnoGIN (Ponsioen et al., 2006).



2.2 TechnoGIN Approach for Karnataka case study

The main quality of TechnoGIN is that it allows to quantify the required amount of various inputs such as labour, fertilizer, pesticides, seeds, animals and irrigation with their monetary values to attain target yields on a yearly basis, consisting of a single crop or a crop rotation. These monetary values are used to calculate net profits by deducting input costs from gross profits obtained from farm gate prices of different crop rotations in both districts, Mysore and Chitradurga. Profits will determine whether organic agriculture is more beneficial than conventional agriculture in economic terms. TechnoGIN can also show the cost and profit difference between various crop rotations in the two districts. This can be used to know the difference of the risk of debts between various crop rotations in conventional and organic agriculture. In addition, the model also calculates different static resource balances which can have negative or positive balances. For example, the crop nutrient balances of N, P and K can be positive, indicating soil reserves or negative, showing mining of soil nutrients resulting in unsustainable crop production. The model also calculates nitrogen losses and a biocide index, which result into pollution of the environment.

2.3 Scenarios comparing organic and conventional

In the current situation, the farms in both districts, Mysore and Chitradurga, use the same crop rotations for both conventional and organic agriculture. On average, farmers have three cattle in their own fields. The manure comes from these three cows and is mixed with farm wastes and then kept in open or closed pits, which results in 15 tons of farm yard manure. The average land holding size of a farmer is 1 ha, so the farm waste is approximately from 1 ha. The farmers practicing organic or conventional agriculture use these 15 tons of farm yard manure to apply in their own fields. Organic farmers are converting farm yard manure into vermicompost with help of a vermicompost pit, which can be used for more efficient nutrient supply on their own farms. There are some cases where farmers do not use all farm yard manure for producing vermicompost due to lack of infrastructure of vermicompost pits or low applications of fertilizer. If the crop nutrient demand is higher than available in farm yard manure or vermicompost, then they have to purchase this from neighbours or from the market which can be costly. Fodder purchased from outside of the fields is not taken into account, as the farmers take their cattle towards common grazing lands nearby the villages for grazing, and supply crop residues from crops.

The input parameters as described below in this Chapter were used to assess the research questions as described in the Introduction. Below the inputs used for the land use systems are summarized, according to different scenarios.

Question 1) Differences organic and conventional farming?
In this scenario we are looking at differences between conventional and organic in the current situation (2009) with respect to economic indicators such as fertilizer costs and profits, and ecological indicators such as water requirements, biocide index, nitrogen losses and nitrogen surpluses. To assess the sustainability of organic systems, not only the reduction in possible debts should be assessed, but also the impact on other economic and environmental indicators. To assess the current situation, the input parameters are used as described in this Chapter 2.5 to 2.13. TechnoGIN calculates fertilizer costs by using an optimization model which searches for the best possible and efficient fertilizer combinations that reach nutrient values that are applied according to the crop sheet (current, technology A-D) and efficient QUEFTS calculations (future/alternative, technology E,F). These TechnoGIN calculations do not always represent reality, and therefore some more calculations are done. As farmers often do not apply the optimal combination of fertilizers and because the optimization model cannot always be solved, the fertilizer costs are also calculated manually based on actual data. The fertilizer costs in conventional agriculture are calculated by reducing the costs of fertilizer applied by the farmers from its own field which is 15 tons of farm yard manure, which can also be converted into the same amount of vermicompost. The amounts of vermicompost available on average are taken into consideration and are subtracted from the 15 tons of farm yard manure. In organic agriculture, the costs of vermicompost are firstly reduced and then costs of remaining farm yard manure which is not converted into vermicompost is reduced. Ecological indicators such as nitrogen losses, nitrogen surpluses, biocide index also have impacts on the environment so we will be looking at differences in indicators between conventional and organic. As there was lack of data on specific nitrogen loss fractions, we did not distinguish between different pathways of nitrogen loss.

Question 2) Projecting for the year 2015?

In this scenario we are projecting changes that can take place in conventional agriculture and organic agriculture for the year 2015 with respect to economic and ecological indicators. For these systems, most input parameters are similar as described in this Chapter 2.5 to 2.13, except from a few assumptions about changes in the future. Yields are expected to stay the same, as regressions showed there were no increases in last three years. For organic products a 30% price premium of conventional product is assumed. Prices of conventional products are assumed based on results of regression analyses on farm gate prices and extrapolated towards the year 2015. Costs of chemical fertilizers also remain the same as there was no increment in the price in the past three years. As for the current situation, the costs of fertilizers in conventional agriculture for the year 2015 are calculated by deducting the costs of fertilizers applied by the farmers that are coming from their own farms, which is 15 tons of farm yard manure. In organic agriculture, the costs of vermicompost are firstly deducted, and subsequently the costs of remaining farm yard manure. The costs of pesticides always fluctuate; the values for the year 2015 are based on the trends in the past five years, using regression analysis.

Question 4) Impact of crop failure on debt?

In this scenario we are looking at a specific economic indicator, which is the risk of debts due to crop failure. Assessments are performed for conventional and organic agriculture in the current situation (2008) and projections are made for the year 2015. For these assessments, most input parameters are similar as described above in this Chapter 2.3 to 2.13, except for changes in farm gate prices in the crop sheet and labour costs in the technology sheet. Farm gate prices of all crops in both districts of year 2008 and 2015 are set to 0 and labour cost for harvesting are set to 0, because there is no harvesting of crops. Total crop failure is assumed, so no farm gate price and no labour cost for harvesting.

Question 5) Impact of improved nutrient management?

In this scenario we are looking in more detail at the ecological indicators N balance and N losses. Optimal nutrient management is simulated for different crop rotations by using alternative/false system resulting in zero nutrient balances in the soil. This is done for both conventional and organic systems, for the current and future situation, and for both districts. For these assessments, in the technology sheet two different technologies E and F were defined, where the option of false system is selected (see technology sheet). In this scenario, most input parameters are similar as described above in this Chapter 2.3 to 2.13. However, an alternative/false system is assumed, and fertilizer application is calculated by QUEFTS, instead of using data on the current fertilizer application as in the current/true system. As there were few data on soil nutrient supply, a sensitivity analysis was performed. Besides the assumption of soil N supply which is 114 kg N/ha, optimal nutrient management was also estimated for soil N supply of 50.5 kg N/ha (see nutrient sheet) in red sandy loam and red sandy soils of Mysore and Chitradurga districts. Considering the low organic carbon content and the low yields, it is possible that the soil N supply is lower than officially reported.

2.4 TechnoGIN data bases for case study in Karnataka

For the Karnataka case study, two separate database files have been produced for Mysore and Chitradurga. These files contain the data bases in separate worksheets for the respectively crops (Crop Sheet), Land use types or crop rotations (LUT sheet), Land management units (LMU sheet), fertilizer types and costs (Fertilizer sheet), nutrient cycling including factors for nutrient leaching, fixation and volatilization in aerobic and anaerobic farming (Nutrient Sheet), money or local currency equivalent to dollars or Euros (Currency Sheet) and yield related resource use efficiency factors (Efficiency Sheet).

The contents of each worksheet are described in subsequent sections of this chapter. The data collected to fill in the contents of these worksheets are from expert knowledge of scientists, literature reviews, and farm and field surveys in the villages. Data were also collected from ATREE (Indian NGO) as described in Purushothaman et al. (2009) and the Indian government websites.

2.5 Crop sheet

In this worksheet, data specific per crop are mentioned. The crops data are also separated per production orientation: a) organic and b) conventional. Furthermore, the crops are distinguished according to seasons, as crops in different season may have different crop duration of a season, yields, and other characteristics. There are three different cropping seasons:

<u>Kharif season</u>: This is the main season in the farmer's perspective, because in this season there are monsoon rains brought by the southwestern monsoon winds, which blows from the Indian Ocean and Arabian Sea. As 70% of the agricultural land is under rainfed agriculture (Census 2001) rain is the most important source of water for crop cultivation. The season extends from June to September.

<u>Rabi season</u>: This is the winter season in India. The climate is warm but sometimes there are rainfalls brought by northeastern monsoon winds. This season is from November to February.

<u>Summer season</u>: In this season the climate is very hot and humid. There are very few chances to grow any crops, as there is no rainfall and the evapo-transpiration is more than the other seasons, so the crop productivity is also low. This season is from February to May.

There are different crops grown in different districts a) Mysore and b) Chitradurga. A wide variety of crops are grown in these regions, including ragi (finger millet), sugarcane, arecanut, maize, sorghum, bajra (pearl millet), chillies, grapes, coconut, rice and groundnut. In the model, according to the field survey only the crops which are important and cultivated at a large scale, are taken into consideration. The land use types are crop rotation that are mentioned in next sheet of LUT and include the crops:

Chitradurga: maize, ragi, onion, sunflower, groundnut

Mysore: rice, cowpea, cotton, sugarcane, coconut, tur-lentil, sesame

Each row includes one crop grown in one of the three seasons and based on either a conventional or organic production orientation. Each column includes certain data that are used in the model to calculate input-output coefficients.

2.5.1 Crop number

In first column there are numbers given to each crop, which are used in the LUT sheet to indicate the crops in a land use type. The same crop can be mentioned in different land use types, but will refer to different crop numbers when the orientation (organic/conventional) or the season (kharif, rabi and summer) is different.

2.5.2 Crop code and name

In the second and third column the crops code and crops full names are mentioned. The first three columns are as follows for some examples in Chitradurga:

- MaKC Maize-kharif-conventional
  This defines the maize crop grown in the kharif season and by conventional method.

- RRO Ragi-Rabi-Organic
  This defines the ragi crop grown in the rabi season by organic method.

- RiSO Rice-Summer-Organic
  This defines the rice crop grown in the summer season by organic method

Exceptions are sugarcane and coconut, which are perennial crops, so they are not distinguished according to seasons: SC= sugarcane conventional and SO = Sugarcane organic, CocoC – Coconut conventional and CocoO = Coconut Organic.

2.5.3 Maximum dry matter yield

In the fourth column the data that has to be presented is the dry matter yield of the crops in optimal conditions. This is the potential yield of the crop using best management practices. The potential yield can be considered as the crop production without any nutrient and water limitation and no losses due to any pest and disease attacks in the field. The data are obtained from J. Wolf (pers. comm.) based on his expert knowledge. These crop data are derived from the crop data files of the WOFOST model (Lazar & Genovese, 2004) and TechnoGIN system (Ponsioen et al., 2003, 2006). It is expressed in the unit tons/ hectare (t/ha). This value remains constant per crop species, despite of having different growing seasons and different farming methods such as conventional and organic methods. The value is used for calculations of the nutrient cycle in QUEFTS; values do not need to represent the exact potential yield in the region because the data of potential.

2.5.4 Harvest index

In the fifth column data on harvest index, i.e. yield / total biomass, is expressed as dry matter or the harvest index percentage divided by 100. The harvest index data is also based on J. Wolf (pers. comm.). The value varies with different crop species only.

2.5.5 Dry matter percentage

The sixth column denotes the dry matter percentage in the crop yield. The values are more or less close to 85-95% in the cereals and legumes. Exceptions are there in onion, sugarcane and coconut having values of 30, 20 and 53 % respectively. These data are obtained from J. Wolf (pers. comm.), and are based on his expert knowledge. These crop data are given in the crop data files of the WOFOST model (Lazar & Genovese, 2004) and TechnoGIN system (Ponsioen et al., 2003, 2006).

2.5.6 Nitrogen fixation

The seventh column shows fNfix, which is the fraction of nitrogen uptake supplied by symbiotic fixation of legumes such as groundnut and lentil tur-dal. Normally these values are set to a default value of 80% for leguminous crops. The value remains the same for both conventional and organic cultivation and in any season.

2.5.7 Maximum and minimum Nitrogen, Phosphorous and Potassium in crops

From the 8th till the 20th column, the data required are the minimum and maximum nitrogen, phosphorous and potassium concentration in the harvested products and in the crop residues. These values are used in QUEFTS for calculation (Wolf & Hengsdijk (2003). These data are used to assess how much N accumulation takes place when N supply and N uptake is high, while there are limitations of other nutrients such as Phosphorous and Potassium. At that time there is highest concentration of N in the crop products and its by-products. When there are no limitations of other nutrients in supply and uptake by the crop at that time, there is maximum dilution of the nitrogen in the crop, and then there is a minimum concentration of Nitrogen in the crop products and its by-products.

2.5.8 Duration of crops

In 21st column the data required is the duration of crops in days. Duration of crops starts from the day of land preparation itself, including the crop establishment period and ends at the day of crop harvesting. These data vary between different crop species. The days required for the land preparation and harvesting for every crop are almost the same because still the traditional methods are used for small and fragmented land cultivation and harvesting practices are homogenous among crops. But the crop establishment period varies between different crop species. There are long duration crops which stay almost one year, such as sugarcane and coconut. There are short duration crops such as ragi, cowpea, sunflower, sesame and onion; their duration ranges from 100-110 days. The duration of other cash crops such as cotton, rice, maize and tur lentil ranges from 120-150 days. These data were taken from the farm visits in the village where I took interviews of farmers and they were also rectified by the agriculture officer of the Agricultural Information centre (Krushi Vigyan Kendra) of both villages Hiriyur and Mysore. Data were further checked with literature from Allen (1998).

2.5.9 Crop coefficients

The 22nd to the 58th column are filled up by the crop coefficients of the crop. The crop coefficient is defined as a simple ratio of evapotranspiration observed for the crop studied over that observed for the reference crop under the same condition (Allen et al., 1998). In the model the crop coefficient KC will be multiplied with potential evapotranspiration to calculate maximum evapo-transpiration (assuming that water supply is not limiting). These data will be used for the water requirement of the crop and in the results we can identify if the water requirement of the crop for establishment has been met or not. These data were taken from literature of Allen (1998). The data mentioned in this literature were for well managed crops in sub-humid climate. The crop coefficient in every crops species is different in different crop stages such as initial stage, crop establishment stage vegetative and flowering stage and harvesting or maturity stage. The values are averaged coefficient values in different crop stages, so we can use them in our worksheet. I took support of previous databases of Burkina Faso case study (Wolf, 2004), Dingras case study (Laborte et al., 2006), Pujiang case study (Van de Berg et al., 2007) for crops like rice, maize etc. We also have to take notice that the model applies a minimum value of KC=0.2, assuming soil evaporation from fallow land. Now the year is divided into 36 dekads; each dekad consists of 10 days. Table 2.1 shows values for a few crops.

Table 2.1 Examples of values of crop coefficient (Allen 1998).

Crop	Kc Initial	Kc Mid	Kc End
Sugarcane (after 3-4 months)	0.4	1.25	0.75
Rice	1.1	1.2	0.6
Ragi	0.3	1.0	0.3

2.5.10 Required labour days

In the 59th column and following till 62nd, data are required labour days. It is very hard to get perfect data on labour days required for a crop in a particular season. Most of the farmers are dependent on rainfall for their crop production. The rainfall in these areas is erratic and unpredictable, which leads farmers to have sudden spontaneous work of land preparation or harvesting in their own fields. Delay in work may lead to crop failure. In the peak season the labour availability is very scarce; therefore there are huge problems of labour in those peak periods. Rainfall in the harvesting stage also creates panic, as the farmers wants to finish their harvesting before any heavy rains, which may cause high damages to the crops. Hence, labour requirements are variable and cannot be estimated exactly. We took the average of the data on labour required for different crop species collected by a) the farm surveys done by the ATREE, b) expert knowledge of scientist of the agriculture information centre and c) the field survey done by myself in the villages. The labour requirements are classified into four stages, a) land preparation b) crop establishment (fertilizer broadcasting) c) crop management (labour required for weeding, interculturing) d) harvesting.

Except for harvesting, the units are labour days/ha. For harvesting it is labour days/tons of crop production. Labour days are defined as one person working for one day. Now the situation in the Karnataka case is that the farmer hires 50 % man labour and 50% woman labour and has to hire in total more than 10 labourers to finish the work of harvesting within one day for 1 hectare (Table 2.2), so I counted 10 labour days for that particular farm work. The labour days required are different per crop species, but are the same for both conventional and organic farming (except rice crop

Table 2.2), because most of the work is done traditionally by their own family and hired hand labourers. They also do not use herbicide for weeding.

Table 2.2 Labour days required for different crops mentioned in the Crop Sheet.

	Land prep	crop est.	crop man.	Harvesting
	ld/ha	ld/ha	ld/ha	ld/ton
Maize	27	21	11	39
Sunflower	10	10	10	6
Groundnut	12	16	14	16
Ragi	10	10	10	10
Onion	40	35	5	2
Cotton	15	15	15	26
Cowpea	10	10	10	9
Rice Con	48	24	12	7
Rice Org	48	24	15	7
Tur Lentil	10	10	10	9
Sesame	10	10	10	10
Coconut	30	3	3	3
Sugarcane	20	36	36	2

2.5.11 Seed requirements per hectare

The 63rd column refers to the seeds requirement in kg/ha. These data have been included in kg/ha, except for sugarcane and coconut crops, as these are mentioned as sets/ha and plants/ha. This is fine when the seed costs (column 80th) are also expressed in rupees per sets or plants instead of per kg, in order to obtain the right value for total seed costs. The seeds requirement depends upon the size and weight of a seed and seed rate of that particular crop species (Table 2.3). The seed rate also depends upon the farmer’s choice. The data are average data of the farm survey and experts knowledge of officers in National Seeds Corporations of India. This government enterprise is one of the main institutions who are responsible for the distribution of the seeds in India.

Table 2.3 Seed rate of various crops by farm survey.

Crop	Seed rate (kg/ha)
Rice	100
Cotton	0.7
Maize	17.6

2.5.12 Fuel, machine and animal Cost

As there is no mechanization on the farms of Chitradurga and Mysore district, the costs of the fuel (litres/ha) and machines (hours/ha) are set to value 0. The farmers require the animal ox for ploughing agricultural land, which takes 3 days having 8 hours per day for ploughing one hectare of land. These are sum up to 24 hours of animal requirements per hectare of land. These data are taken from the farm survey done by ATREE and own field visits.

2.5.13 Irrigation cost/hour and irrigation water

Data for irrigation are taken from the farm survey of ATREE and own farm visits. The current availability of electricity was discussed with the farmers. The farmers argued that there is no constant electric current, not even for two hours, to the motor pumps which are used for irrigating the fields. Normally they use the flooding method for irrigating their farm. The electricity is free, so there is no cost of irrigation except the mechanical cost of the motor pumps but it is very low, so it is not taken into consideration. Normally, irrigation is always required during the rabi season and summer season. Most rainfed farmers don't cultivate crops in the summer. Values are only used for calculating the nutrient supplied by irrigation water. Irrigation water applied has been based on values from the given websites 'water requirement of different crops in India. The data can be found on the given website of India Agronet and the Natural Resources System Programme (Anonymous, 2009l, m) and the coconut development board website for coconut plants (Anonymous, 2009h). This value will be useful for the nutrient supplied by water which is received by irrigation.

2.5.14 Investment and land rent

Investment and land rent value per hectare is taken as zero, as the farmers do not invest money for any land improvements such as terracing, bunding, erosion checks. They do not have any idea about these systems and measures and they are not aware of losses due to soil erosions. There is a loss of 20-40 tons of soil per ha from soil erosion according to Dr V. Ramamurthy from the National Bureau of Soil Survey, August 2009 (pers.comm).

2.5.15 Dekads requirement for land preparation and harvesting

Dekads required for the land preparation and harvesting is set to 1 as the farmers don't take any chances of late harvesting and land preparation. According to the farm survey, the farmer will increase the labour in the farm to complete its harvesting and land preparation as soon as possible to reduce the risk from natural damage.

2.5.16 Aerobic or Anaerobic

In this column we have to mention the farming condition as aerobic or anaerobic. Except for the rice crop which is grown in anaerobic conditions the value only has the true option.

2.5.17 Biocides

Data on the amounts of different types of biocide applied (kg or liter per hectare) are taken from the farm survey data of ATREE, data received while having direct interviews with farmers and also rectified data by the experts or agricultural officer of that area. In general, the farmers have no idea of the active ingredients of any pesticide and even they don't know if it is fungicide, bactericide or insecticide. They spray according to the agricultural expert knowledge of scientist in agricultural information centre and shop wholesaler's recommendation. On an average they spray around 2 litres or kg/ha of total biocides in some conventional crop production such as sugarcane, rice, cotton. Different types of biocides which are applied; their characteristics are included in the Biocide sheet.

2.5.18 Farm gate prices

These prices were taken from minimum support prices fixed by the government every year. The data were available from 2006- 2008 for selected commodity such as maize, paddy, ragi, arhar (Tur), cotton, groundnut in shell, sunflower seed, sesamum and sugarcane. The values predicted for 2015 were based on a regression analysis including changes in the minimum support prices of the last 8 years. The observed trend was extrapolated to 2015. Farm gate prices from other crops such as coconut were taken from the farm survey, farmer interviews and market prices. For coconut it was concluded that there was no rise in prices and it stayed at the price of 5.50 rupees per kg. Prices of onion and cowpea were also not included in the list of commodities having minimum support prices. Those prices were taken from the commodity market. The price of onion was provided by the website of India-stat for every month for last few years (Anonymous, 2009d), and market commodity website such as Commodity Online (Anonymous, 2009n). In the case of cowpea, prices were based on Calum and Apurba (2008).

For organic products, the prices at retail level were almost 100-150% more than minimum support price as was observed in many retailing stores in Bengaluru such as Era Organic website: http://www.eraorganic.org/ and Namdhari Agrofresh ltd: http://www.namdharifresh.com. These values were too high to use in the model as the farmers do not get these retail prices. In the current situation when you look at any organic villages in Karnataka you will find out that still there are no organic farms that are certified with any proper certification agencies. Also they lack market infrastructure; hence farmers don't get any premium for their any organic products. With that reference I will assume same prices for organic products as of conventional in current situation. According to Garibay (2003), the price premiums obtained for organic products vary greatly from country to country (10 to 50%) for different organic products (fresh, dry, juice, puree, etc) depending on the distribution channels (supermarkets, restaurants etc). However, an average across countries and products shows that price premiums range between 30-50% (at whole seller level). So I took a premium of 30% on prices of organic products compared to conventional products (except for sugarcane and coconut) for future 2015. In the future, the premiums will not be changed so much according to economic experts. I took a 10% extra premium for organic cotton as there is a huge demand for Indian organic cotton in the world market according to literature of Ferrigno and Nagarajan (2006).

2.5.19 Seed prices

Prices of seeds were based on the data given by the National Seed Corporation (NSC) (Table 2.4), a government enterprise which is responsible for the distribution of seeds throughout the state. The prices included in TechnoGIN include the 50% subsidies given by the Karnataka government. Seeds which farmers buys from private and government agencies are rice, maize, onion, sunflower, cotton, cowpea and sesame.

Table 2.4 Price of seeds of the crops (National Seed Cooperation).

Crop Seed	Price (INR/kg)
Rice	14.5
Maize	12.5
Onion	250
Sunflower	100
Cotton BT, OP’	750, 250
Cowpea	80
Sesame	60

OP’: Open variety for organic cotton cultivation

Seeds of crops like groundnut, ragi, arhar (Tur) are used from their own house, so market value of those seeds are taken as cost of seeds. Seeds of sugarcane are bought from neighbours for 0.5 INR. Coconut plants are bought from the nursery. The data are based on field visits and farmer interviews.

2.5.20 Fertilizer gifts

Fertilizer gifts are taken from farm survey data and field visits in those villages. Farmers apply the same fertilizer to almost every crop (Table 2.5), except the cash crops such as onion, rice and sugarcane (Table 2.6). The value that appears is the amount of NPK applied through the fertilizers for different crop species in conventional and organic farming. The fertilizers in organic farming are vermicompost, farmyard manure and poultry manure (only in Chitradurga). Other fertilizer types and their NPK contents and prices are specified in the Fertilizer sheet.

Table 2.5 Nutrient applied (kg/ha) to crops in Chitradurga district mentioned in Crop sheet.

Srno	Land use types	N	P_2O_5	K
1	Maize-Kharif-Conventional	67	55	136
2	Maize-Kharif-Organic	18	11	15
3	Maize-Rabi-Conventional	67	55	136
4	Maize-Rabi-Organic	30	13	27
5	Sunflo-Kharif-Conventional	67	55	136
6	Sunflo-Kharif- Organic	30	13	27
7	Sunflo-Rabi-Conventional	67	55	136
8	Sunflo-Rabi-Organic	31	13	27
9	Sunflo-Summer-Conventional	0	0	0
10	Sunflo-Summer-Organic	0	0	0
11	Gnut-Kharif-Conventional	67	55	136
12	Gnut-Kharif- Organic	30	13	27
13	Gnut-Summer-Conventional	32	15	48
14	Gnut-Summer- Organic	9	9	6
15	Gnut-Rabi-Conventional	67	55	136

Srno	Land use types	N	P_2O_5	K
16	Gnut-Rabi-Organic	30	13	27
17	Ragi-Kharif-Conventional	67	55	136
18	Ragi-Kharif-Organic	30	13	27
19	Ragi-Rabi-Conventional	67	55	136
20	Ragi-Rabi-Organic	0	0	0
21	Onion-Kharif-Conventional	206	3	13
22	Onion-Kharif-Organic	70	70	60

Table 2.6 Nutrient applied (Kg/ha) to Crops in Mysore district mentioned in Crop sheet.

Srno	Land use types	N	P_2O_5	K
1	Cotton-Kharif-Conventional	45	30	7
2	Cotton-Kharif-Organic	25	19	19
3	Cowpea-Kharif-Conventional	45	30	7
4	Cowpea-Kharif-Organic	25	19	19
5	Cowpea-Rabi-Conventional	54	31	7
6	Cowpea-Rabi-Organic	25	19	19
7	Rice-Kharif-Conventional	130	29	0
8	Rice-Kharif-Organic	43	36	31
9	Rice-Summer-Conventional	130	29	0
10	Rice-Summer-Organic	43	36	31
11	Tur-Lentil-Kharif-Conventional	0	0	0
12	Tur-Lentil-Kharif-Organic	0	0	0
13	Sesame -Summer-Conventional	64	20	0
14	Sesame -Summer-Organic	25	19	19
15	Ragi-Kharif-Conventional	64	20	0
16	Ragi-Kharif-Organic	25	19	19
17	Ragi-Rabi-Conventional	64	20	0
18	Ragi-Rabi-Organic	25	19	19
19	Coconut-Conventional	29	7	29
20	Coconut-Organic	23	5	23
21	Sugarcane-Conventional	168	58	120
22	Sugarcane-Organic	109	88	80

2.6 Land use types sheet

This database includes the possible land use types that can take place in areas of Chitradurga and Mysore. According to season, plantation of different crops is done. Normally in areas of Chitradurga the farmer would prefer only two crops per year; but the farmers who have irrigation facilities may go for summer cultivation as well. In Mysore, most farmers prefer to have three crops per year.

2.6.1 Land utilization number, names and codes:

The first, second, and third column in this sheet denote number, code and full name of the rotation. The land use types also distinguish between methods of cultivation such as conventional or organic method, and are based on the crops identified in the Crop sheet. The total number of combination of land use types in Mysore and Chitradurga is 36 and 48.

Below are the examples of some land use types

MaKC-SuRC: Maize-sunflo: This defines a crop rotation of maize in kharif and sunflower in rabi which are cultivated by conventional methods.

OKC-RRC-GSC: Onion-Ragi-Groundnut: This defines a crop rotation of onion in kharif, ragi in rabi and groundnut in summers which are cultivated by conventional methods.

RKC-CpRC-RSC: Rice-Cowpea-Rice: This defines a crop rotation of rice in kharif, cowpea in rabi, and again rice in summer which is cultivated by conventional methods.

MaKO-SuRO: MaizeO- sunfloO: This defines a crop rotation of maize in kharif and sunflower in rabi which are cultivated by organic methods.

OKO-RRO-GSO: OnionO-RagiO-GroundnutO: This defines a crop rotation of onion in kharif, ragi in rabi and groundnut in summers which are cultivated by organic methods.

RKO-CpRO-RSO: RiceO-CowpeaO-RiceO: This defines a crop rotation of rice in kharif, cowpea in rabi, again rice in summer which is cultivated by Organic methods.

2.6.2 Crop codes in Crop sheet

The fourth, fifth and sixth column denotes the crop numbers as coded in first column of Crop sheet in TechnoGIN. The codes of each crop are in front of each land use types.

2.6.3 Fodder fraction and Burning fraction

The sixth, seventh, and eight column is the fodder fraction of the crop 1, 2 and 3 (Table 2.7), and ninth, tenth and eleventh are the burn fraction of the same crops 1, 2, and 3 of the same land use types. The number coming out of 1–fodder fraction–burning fraction will be used as the fraction of buried waste which is recycled, and used in calculations of the nutrient cycle. The fodder fraction is 0.7 for maize, 0.2 for sugarcane, 0.0 for coconut and 0.25 for all other crops. The burn fraction is 0.3 for maize, 0.7 for sugarcane and 0.25 for all other crops. The information about the fodder and burning fraction were obtained from own farm visit.

2.6.4 Dekads for crop production

The ninth, tenth and eleventh column show the dekad (see Crop sheet) of starting crop production. Initiation of crop 1, 2 and 3 are in different dekads. The data of dekads where initiation crop production are set including the days for land preparation. Thus dekad 16 shows the crop which are grown in kharif season (June-September), 30 shows the crops which are grown in rabi season (October-February) and 6 shows the crops which are grown in summer season (March-May). Normally a farmer takes 30 days for the land preparation in kharif season and in rabi seasons. These data are taken from farm survey and the own fields visit in India.

2.6.5 Technology level

This column denotes which technology should be used in the getting TechnoGIN results for current and future (2015) either with conventional and organic methods. There are different technologies A, B, C, D, E which have further specifications on labour, machinery use, recovery fraction of applied fertilizer. These are all constituents of the Technology sheet which will be explained later (see Technology sheet).

2.6.6 Current/false system

Current systems are input and output relationships based on farm surveys and other sources such as current fertilizer application in fields. The false systems on the other hand are calculated by the model. They are based on production ecological insights that take improved techniques into account, resulting in more efficient use of inputs and or higher yields. It will be set TRUE for the 2008 situation, because I want to calculate the input-output relationships based on fertilizer application data supplied of both organic and conventional fields. If set to FALSE, crop rotation is considered as a future one which is never evaluated for current conditions and it will calculate optimal fertilizer management. It is possible to include the FALSE option in the Technology sheet (see Technology sheet).

2.6.7 Low and high target yields

The database used for the low target yield crops is the current (2008) mean yield in conventional and organic farms in both of the districts Chitradurga and Mysore. As we can see there are large differences in the yields of the same crops between two districts due to different weather conditions (Table 2.7 and Table 2.8). Now setting the High target yield, values, which are assumptions of same crop rotation for 2015, we consider there would be no change in management practices in the future, so yield will remain the same in both conventional and organic farms. We also look at the trend of the average yield of main crops for last five years and there is no major change in the yield (Anonymous, 2009l). Hence the yield in low target (current 2008) and high target (future 2015) will remain the same. These data were collected from the farm surveys conducted by the NGO ATREE. Also expert knowledge of a scientist from Agricultural Information Centre, and own field visit. These data are not exact figures due to variability of yields among the farms and the variation in data given by the farmer during the interviews.

Table 2.7 Data of low (Current 2008) and high (future 2015) target yields of crops (tons/ha) of Chitradurga in Land use types sheet.

Sr No	Crops (Chitradurga)	Current 2008 yield & Future 2015 yield (t/ha)
1	Maize-kharif-Conventional	3.7
2	Maize-Kharif-Organic	1.8
3	Maize-Rabi-Conventional	3.4
4	Maize-Rabi-Organic	5.5
5	Sunflo-Kharif-Conventional	1.5
6	Sunflo-Kharif- Organic	1.8
7	Sunflo-Rabi-Conventional	1.5
8	Sunflo-Rabi-Organic	1.5
9	Sunflo-Summer-Conventional	1.3
10	Sunflo-Summer-Organic	0.9
11	Gnut-Kharif-Conventional	1.5
12	Gnut-Kharif- Organic	2.4
13	Gnut-Summer-Conventional	0.9
14	Gnut-Summer- Organic	1.0
15	Gnut-Rabi-Conventional	1.6
16	Gnut-Rabi-Organic	1.5
17	Ragi-Kharif-Conventional	3.0
18	Ragi-Kharif-Organic	1.8
19	Ragi-Rabi-Conventional	3.0
20	Ragi-Rabi-Organic	1.5
21	Onion-Kharif-Conventional	14
22	Onion-Kharif-Organic	12

Table 2.8 Data of low (Current 2008) and high (future 2015) target yields of crops (tons/ha) of Mysore in Land use types sheet.

Sr No	Crops (Mysore)	Current 2008 yield & Future 2015 yield (t/ha)
1	Cotton-Kharif-Conventional	2.1
2	Cotton-Kharif-Organic	0.5
3	Cowpea-Kharif-Conventional	1.3
4	Cowpea-Kharif-Organic	0.8
5	Cowpea-Rabi-Conventional	1.2
6	Cowpea-Rabi-Organic	0.9
7	Rice-Kharif-Conventional	3.8
8	Rice-Kharif-Organic	1.8
9	Rice-Summer-Conventional	4.2
10	Rice-Summer-Organic	2.0
11	TurLentil-Kharif-Conventional	0.7
12	TurLentil-Kharif-Organic	0.7
13	Sesame -Summer-Conventional	0.5
14	Sesame -Summer-Organic	0.5
15	Ragi-Kharif-Conventional	4.1
16	Ragi-Kharif-Organic	2.8
17	Ragi-Rabi-Conventional	1.5
18	Ragi-Rabi-Organic	2.0
19	Coconut-Conventional	10.0
20	Coconut-Organic	8.4
21	Sugarcane-Conventional	84.0
22	Sugarcane-Organic	48.0

2.7 Land management unit

The two selected districts have different climatic conditions (Fig 2.1). Chitradurga is located in the central dry zone which means the climate is hot and humid and has very low rainfall. Mysore area is located in transitional zone which means it receives medium or average rainfall.

There were three upland soil types 1) red sandy loam 2) red sandy 3) black soil. Red soil is common in both of the districts. The natural base nutrient (N, P and K) supplies have been determined for the main soil types in Mysore and Chitradurga. The soil which is found in those districts is also known as Alfisols. The values of availability of nutrient in soil of Chitradurga and Mysore are taken from soil analysis done by Forghani (2002) at Gandhi Krushi Vigyan Kendra (GKVK), Bengaluru. The P and K values in Mysore case were taken from the database which was provided by Soil laboratory of GKVK. They (Soil Laboratory) didnot mention about the N values in both of the districts Chitradurga and Mysore.

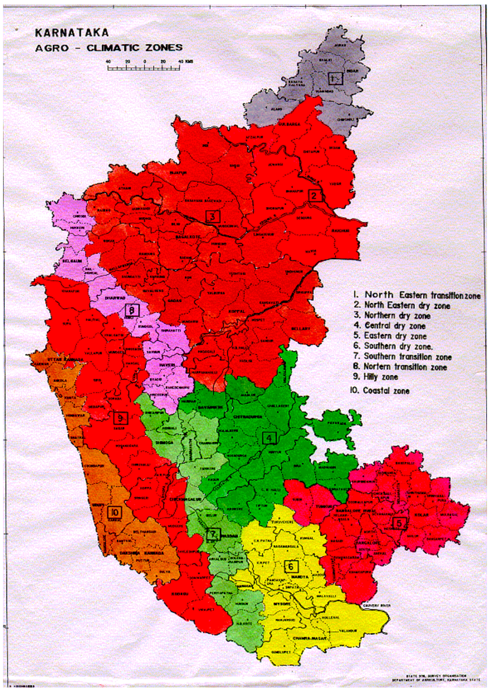


Fig 2.2. Agro-ecological zones of Karnataka.

2.7.1 Acidity, pH, long-term soil supply of Nitrogen, Phosphorous & Potassium

The data in Table 2.10 came from the soil analysis report analyzed by Forghani (2002). It was hard to get data of available nitrogen in both of districts; values given in many articles of Karnataka Agricultural Journals were more than 200 kg N/ha. Agricultural officers of both Hiriyur and Mysore villages had no soil nitrogen data of their own soils. When we looked at the organic carbon percentage in the soil it is less than 0.5% (Sreerangappa et al., 1999). Using pedotransfer functions and data on %

soil organic matter, % organic carbon and C/N ratio (van Keulen, H., P. Reidsma, pers.comm.), inorganic N was calculated, obtaining a value of 50.5 kg N/ha (Table 2.9). This is 4 times lower than the literature value of 200 kg N/ha, and difficult to explain. Therefore, I assumed data of nitrogen in the Forghani (2002) soil analysis report of Alfisols (114 kg N/ha) Vertisols (black soil; 130 kg N/ha) as ideal value for nitrogen base supply in both of districts Mysore and Chitradurga. Due to lack of soil report of Chitradurga, I also have to assume phosphorous and potassium data from the soil report of Forghani (2002) (Table 2.10). In case of Mysore the data of phosphorous and potassium is taken from the soil analysis report given by the soil laboratory GKVK, Bengaluru.

Table 2.9 Calculation of available nitrogen based on data of % soil organic matter, % organic carbon and C/N ratio from Sreerangappa (1999).

	parameters	calculations
effective rooting depth (m)	0.38	
bulk density (tons/m3)	1.4	
soil (kg/ha)= rooting depth * bulk density		5320000
% OM (ratio)	0.0086	
organic matter at 38cm depth (kg/ha) = soil * % OM		45752
% OC (ratio)	0.46	
organic carbon at 38cm depth (kg/ha) = % OC * organic matter		21046
C/N ratio	12.5	
organic nitrogen at 38cm depth (kg/ha) = 0.08 * organic carbon		1684
mineralisation (ratio)	0.03	
inorganic nitrogen (kg/ha) = mineralistion * organic nitrogen		**50.5**

The value 50 kg/ha nitrogen is used in a sensitivity analysis to assess N losses and N surplus and to compare with results based on data provided by Forghani (2002).

2.7.2 Maximum soil water (mm)

Maximum water storage of water in the rooted top soil (between field capacity and wilting point) was set to 100mm assuming 80 cm in Mysore districts and 50 mm in Chitradurga as depth is 25-50cm and also an available moisture fraction of 12.5%. These data taka are taken from the map which was provided by the National Bureau Soil Survey (NBSS) Bengaluru. It is used for calculation and determining the irrigation water requirements.

2.7.3 Elevation and slope

Elevation is not used and there was no data. The database for slopes was taken from the soil maps provided by the NBSS August 2009, and were used in this sheet.

2.7.4 Precipitation (mm/year)

These data in this column are not used in the TechnoGIN for calculation. The data used for precipitation in both Mysore and Chitradurga are averages of precipitation that had occurred since 3 years. The data of 3 years precipitation is taken from Indian Government information website (Anonymous, 2009b).

2.7.5 Sand, silt, clay percentage

The data are based on the soil texture of both Mysore and Chitradurga district. Soil present in Mysore is sandy loam and in Chitradurga is sandy; so according to the sand, silt and clay triangle (Stevens, 1991) the data is mentioned in the Land Management Unit sheet (Table 2.12).

Table 2.10 Description of soils mentioned in LMU sheet.

Districts	Sr. no.	Symbol	Description	pH	N (Kg/ha)	P (Kg/ha)	K (Kg/ha)	Sand	Silt	Clay	Texture
Chitradurga	1	RSS	red sandy soil	6.5	114	23.3	280	65	11	33	Sandy clay
	2	BS	black soil	8.5	130	9	350	10	33	55	Clay
Mysore	1	RSL	red sandy loam	7.4	114	40.8	396	55	30	15	sandy loam

2.7.6 Current class, drainage, parent material, soil classification, permeability rate and bulk density

These parameters are not used for calculation in TechnoGIN. But still database on current class, drainage were classified into class 1, 2 mentioned in TechnoGIN. The data of soil parent material were taken from the soil maps which were provided by NBSS, Bengaluru.

2.7.7 Monthly rainfall (mm/month)

The data used for precipitation in both Mysore and Chitradurga are averages of precipitation that had occurred the last 3 years (Table 2.11). The data were mentioned on weekly basis and taluka wise for three years in the website. The data of 3 years precipitation is taken from Indian Government information website (Anonymous, 2009b). Now it is very interesting to look at Table 2.11, since last three years average rainfall in Chitradurga is more than Mysore. It has more rains in the month of September, October and November. Therefore it seems the rainfall pattern has changed. In the last 3 years the Kharif crop doesn't get adequate water by rains during crop establishment stages but had more rains during harvesting dekads of the crop, which could reduce the production. There is enough rainfall in October and November to get adequate supply of water for early sowing rabi crops. For summer crop they really have to depend on irrigation system.

Table 2.11 Average Rainfall in Chitradurga and Mysore (mm/month) (Anonymous, 2009b).

	Chitradurga	Mysore
Jan	0.0	0.0
Feb	0.0	0.0
Mar	0.0	0.0
Apr	0.0	0.0
May	0.0	0.0
Jun	93.0	53.8
Jul	58.0	63.2
Aug	47.7	68.7
Sep	143.3	120.7
Oct	101.3	62.7
Nov	68.3	106.0
Dec	6.0	0.0

2.7.8 Reference evapotranspiration (mm/dekad)

The data were taken from the Indian government information website (Anonymous, 2009c). The data are average potential evapotranspiration per day in every month. These data are multiplied with 10 as we need data for each dekad. The evapotranspiration changes every month in both districts Chitradurga and Mysore. The database of evapotranspiration was also mentioned district wise.

2.7.9 Rainfall per dekad (mm/dekad)

The data as mentioned above (2.7.7) is weekly wise and it is easy to convert into dekads. There are 3 dekads or 4 weeks per month so I calculated average rainfall in mm in first week and mid of second week so it can be calculated to mean rainfall of whole dekad.
Now for the water or irrigation demand for each crop and different land use types we can take the reference of these evapotranspiration and rainfall data per dekad

2.8 Technology sheet

The technology sheet contains different production techniques (Table 2.12). The different production techniques are different technologies which farmers have been using currently or improved ones. For example, a farmer having low production (Technology: Conv actual), or a technology which will be used in the future which can have higher production in future (Technology: Conv 2015). In each technology there are different options determined by nutrient, biocide and water use efficiencies which may or may not change according to different technologies. Other different systems will be mentioned further. Now there are 6 different technologies; three of conventional farming and three are of organic farming types. Here the parameters are in different rows and arranged from up to down order.

2.8.1 Yield level

In this row we have to mention about different technology level or production techniques that will be used. In A and C the low target yield having level name as conventional actual (Current) and organic actual (Current) are selected. The low level will be used to calculate profits from the low target yield of crop (see LUT sheet). Now the low target yield refers the current (2008) yields in the conventional and organic farm. In B, D, E and F high target yield level having level name as Conv2015, Organic2015, Organic2015Q, Conventional2015Q are selected. The high level will be used to calculate profits form the high target yield of crop (see LUT Sheet). This high target yield refers to the possible yield in future year 2015. But in our study yields stay the same for future 2015.

2.8.2 Nutrient Recovery fraction

The value in nutrient recovery fraction is a correction factor which is multiplied with the recovery fraction of applied nutrients present in the nutrient sheet. If a technology improves nutrient use efficiency, the correction factor is set > 1.0. There is no data indicating increased nutrient use efficiencies for the selected technologies and hence there is no difference between technologies. We are also considering there is no improvement in management practices in conventional and organic farming in the future.

2.8.3 Biocide Use

This parameter or factor is set to 1.0 in organic and conventional farming. This relative factor multiplies with the standard biocide application which is in the Crop Sheet. The use of biocide in Organic is 0 while the farmers in conventional farming do not go beyond the standard pesticide application, as observed in own field visits.

2.8.4 Yield loss fraction

This is the fraction of nutrient limited yield that is lost by the pest and diseases damages. The loss fraction is set to 0.

2.8.5 Relative labour input

This factor is also set to 1 as there would be no addition of the labour days on the conventional and organic farming in future. This factor multiplies with the labour requirement for performing different field works such as land preparation, crop establishment per hectare.

2.8.6 Water use

This is also set to 1 (default), as the factor multiplies with the present evapotranspiration coefficient in the Crop sheet.

2.8.7 Current and future systems

The technology level A, B, C and D are set to the TRUE systems and E and F are set to FALSE system (Table 2.12). In TRUE system all crop rotation in current year 2008 and future in the year 2015 are set to TRUE (see LUT sheet). They use current fertilizer gifts applied (see Crop sheet) for the nutrient calculation. While in FALSE system all crop rotation in the year 2015 are used, but in this system QUEFTS calculates and optimizes the required nutrients for the crops and different land use types. It is based on production ecological insight that takes improved techniques into account, resulting in more efficient use of inputs and/ or higher yields.

2.8.8 Labour cost

The database is according the average of the labour wages in the year 2008 of men and women, which is 75 INR/labour day. The reference of these data is taken from farm survey, and data provided by Indiastat (Anonymous, 2009d). The data for the future is the regression of the average the labour paid in the Karnataka state for the last 5 years and is extended to 2015, which is 115 INR/labour day. There is fluctuation in wages which depends on the government policy NREGA (National Rural Employment Guarantee Act). The labour wages are paid per labour day irrespective of any farm work labour does in the farm.

2.8.9 Input cost

Except the animal rent which is 12.5 INR/hour, the farmers do not have any cost as they have no mechanical tools or implements in their farm. The electricity use for the pumping the water from the tube-wells is free of cost, so no cost for irrigation. We still assume that the state government will provide free electricity to the farmer.

2.8.10 Relative input

Animal use is set up to 1 as this factor is multiplied with the data present in the crop sheet on the use of fuel, machine and animals. There are assumed to be no changes further in future in 2015 as the farmers are assumed to be still poor and posses small fragmented lands and it’s difficult to bring mechanization in their own farm.

2.8.11 Limit fertilizer type (kg/ha/crop)

These are rows where limitations can be set for each specified fertilizer type per technology. The technologies A, B and F are conventional ones where the chemical fertilizers such as urea, di-ammonium phosphate, muriate of potash, 20-20-0 and 10-26-26 have limits of 500kg/ha/crop which are 10 bags per hectare per crop. The technologies C, D, and E are organic ones with organic fertilizer such as vermicompost and farm yard manure which have their limitation at 15000kg/ha/crop and poultry manure with 5000kg/ha/crop. The limitation for conventional farms of organic fertilizers is also set up to 5000kg/ha. Adaptations were made with the values of fertilizer limits, because the nutrient concentrations in the fertilizer types were adjusted in the fertilizer sheet, as TechnoGIN did not run with values below 1.0 (see section 2.11). We considered one fourth of required farm yard manure fertilizer (=3750 kg/ha) and half of required vermicompost (=2500 kg/ha) because in the fertilizer sheet, we multiplied the nutrient values of farm yard manure by four times and vermicompost by two times. The limitation is also based on the average capacity of a farmer to buy and apply different fertilizers in his own field. The fertilizer types are optimized according to prices (see fertilizer sheet). Conventional technologies have a limit of 0 for organic fertilizer, organic technologies a limit of 0 for inorganic fertilizers (Table 2.12).

Table 2.12. Technology sheet in TechnoGIN.

Technology levels		Conv actual	Conv 2015	Organic actual	Organic 2015	Organic 2015Q	Conv 2015Q
	Level	**A**	**B**	**C**	**D**	**E**	**F**
	Yield level (low or high)	Low	High	Low	High	High	High
Nutrient recovery	Nitrogen	1	1	1	1	1	1
	Phosphorus	1	1	1	1	1	1
	Potassium	1	1	1	1	1	1
Biocide use	Pesticide	1	1	1	1	1	1
	Fungicide	1	1	1	1	1	1
	Insecticide	1	1	1	1	1	1
Pest & disease	Loss fraction	0	0	0	0	0	0
Relative labour input	Land preparation	1	1	1	1	1	1
	Crop establishment	1	1	1	1	1	1
	Management	1	1	1	1	1	1
	Harvest	1	1	1	1	1	1
Water use	Evapotranspiration	1	1	1	1	1	1
Current/future	Use of current systems	TRUE	TRUE	TRUE	TRUE	FALSE	FALSE
Labour cost	Land preparation	75	115	75	115	115	115
	Crop establishment	75	115	75	115	115	115
	Management	75	115	75	115	115	115
	Harvest	75	115	75	115	115	115
Input cost	Fuel cost per litre	0	0	0	0	0	0
	Machine rent per hour	0	0	0	0	0	0
	Animal rent per hour	12.5	12.5	12.5	12.5	12.5	12.5
	Irrigation cost per m^3	0	0	0	0	0	0
Currency & year	Input currency	INR	INR	INR	INR	INR	INR
	Year	2008	2015	2008	2015	2015	2015
	Output currency	INR	INR	INR	INR	INR	INR
Relative input	Fuel use	0	0	0	0	0	0
	Machine use	0	0	0	0	0	0
	Animal use	1	1	1	1	1	1
Limit fertiliser type	Urea	500	500	0	0	0	500
	Di- ammonium phosphate	500	500	0	0	0	500
	10-26-26	500	500	0	0	0	500
	Farm Yard Manure	3750	3750	3750	3750	3750	3750
	Vermicompost	2500	2500	2500	2500	2500	2500
	Poultry Manure	0	0	2500	2500	2500	0

2.9 Efficiency sheet

These data are related to overall efficiency of nutrients, biocides and water use in terms of fraction to achieve different percentage of the yield not based on different production techniques. This concept also shows that input use efficiency decreases with higher application rates to achieve maximum yield. Normally maximum yield is maximum dry matter yield of the crop which is mentioned in the crop sheet. These factors apply to all land use types and land management units.

2.9.1 Nutrients use efficiency (Nitrogen, Phosphorous and Potassium)

In this sheet five reference yields are percentage of maximum yield. There are five reference yields in each different row from 0% yield to 100% yield (Table 2.13). The value in this reference yield is set to 1.0 except for 100% yield because they need higher application of nutrient rates. This will lead to more losses and will decrease the efficiency of the nutrients; therefore at 100% yield the efficiencies are set up to 0.8.

2.9.2 Pesticide, fungicide, herbicide use efficiency

This is the fraction of pesticides that will be used in kg active ingredient/ha for getting the mentioned reference yield. The amounts of pesticides that are used in the farm are mentioned in the crop sheet. The value lower than 1 means less pesticide use, so we can set nil at 0% yield and 0.5% at 25% yield (Table 2.13). Normally when you look at the field in tropical India, there is still always 30-50% yield reduction even after regular pesticide application rate so the amount of pesticides will not decrease at 75 and 50% reference yield. Therefore, the fraction of pesticides still remain the same as the 100% reference yield.

2.9.3 Water use efficiency

More production or more yields will also increase the evapo-transpiration, so a higher crop coefficient value, hence more water requirement. This will increase the water use efficiency at the 75% and 100% reference yield so the fraction value has been set to 1.1 and 1.2 respectively according to Wolf (pers. comm.). Values in other reference yields are set to default 1.0 (Table 2.13).

Table 2.13. Efficiency sheet in TechnoGIN.

Reference yield:	Nitrogen	Phosphorus	Potassium	Pesticide	Fungicide	Herbicide	Water
100%	0.8	0.8	0.8	1	1	1	1.2
75%	1	1	1	1	1	1	1.1
50%	1	1	1	1	1	1	1
25%	1	1	1	0.5	0.5	0.5	1
0%	1	1	1	0	0	0	1

2.10 Biocide sheet

This sheet contains descriptions of different types of biocides used by the farmers, including environmental characteristics such as half life duration in soil, percentage active ingredient and the EPA/WHO index. These are used for calculation of the environmental pollution due to biocide use. According to Pathak et al (2001) a BRI

value of less than 100 can be designated as safe, whereas a value between 100 and 200 is permissible, but a BRI value more than 200 is unsafe with respect to environmental safety. The prices are also specified for each biocide from 2006 to 2015. The data are mentioned column wise in this sheet.
The Biocide Residue Index (BCI) calculates the degree of environmental pollution as follows (Pathak et al., 2001):

BRI = Biocide (g/ha^{-1}) * active ingredient fraction (kg l^{-1} or kg kg^{-1}) * Toxicity in Persistence index /100

2.10.1 Code, type of pesticide

This column represents the serial number or code of the pesticide and second column denotes which type of pesticides are they, for example insecticide or fungicide or herbicide.

2.10.2 Description, active ingredient name

The column of description refers to the name of the pesticides which are available in the market. These names of pesticides are derived from the conventional farmers who used pesticides in their own field from farm survey. In another column it denotes the real active chemical ingredient inside the pesticides. This information can be found in the PAN Pesticide Database (Anonymous, 2009e).

2.10.3 Amount or percentage of active ingredient

The amount of the active chemical ingredient is in kg/litre or kg. These data are taken from the article of Babu et al (1998) and from the PAN Pesticide Database (Anonymous, 2009e).

2.10.4 Half life duration in soil days, EPA/WHO Index code and index number

These are the parameters used for the calculation of the environment pollution into nearby surroundings. The half life duration is the time required by the active chemical for degradation. The EPA/WHO index code and number are the codes and numbers given to the different pesticides according to hazardous nature of the chemical in terms of environment and human and animal health. The values were taken and can be found from several websites (Anonymous, 2009e,f,g)

2.10.5 Prices (INR/litre or kg)

The prices of the pesticides are collected from the market pesticide wholesalers and shopkeepers. The 50% government subsidies are included. The prices are never fixed, they fluctuate every month and it all depends on the demand and supply of the pesticides. Normally the pesticides suppliers are the multinational companies. The prices of pesticides in 2015 are extrapolations of the trends according to regression analyses of prices from the last 5 years. The prices are expressed in INR (Indian Rupees).

2.11 Fertilizer sheet

In this sheet the composition of different fertilizers applied by the farmers of conventional and organic farms in Mysore and Chitradurga districts, their availability in terms of macro nutrients and their prices are specified. The availability of nutrients such as nitrogen, phosphorous and potassium in organic fertilizer are very low due to losses. The Farm Yard Manure which farmers used regularly are kept in the open pit but we also observed closed pits in the survey and visits. A pit is a digged hole in the ground where all the manure and farm waste are buried. The nutrients from the manure fertilizers are lost through nitrogen leaching, volatilization or poor timing of N-mineralization in soil versus the time course of crops nutrient uptake.

2.11.1 Name, dry matter content

In the first column the name or composition of the different fertilizers are mentioned. Normally the nutrients concentrations are mentioned in the percentage content so in next column the value are set to 100%.

2.11.2 N, P and K concentration (% N, P and K)

The values used in these columns (Table 2.14) of nutrient concentration of different fertilizers are derived from the Indian official agricultural information website (Anonymous, 2009i,j). The values mentioned in Table 2.14 of farm yard manure and vermicompost are multiplied by 4 and 2 respectively, as the TechnoGIN solver for optimal fertilizer use does not work with values lower than one for %N. The resulting fertilizer use will thus refer to nutrients present in 200kg and 100kg of fertilizer instead of 50 kg, and therefore fertilizer prices are also adapted (section 2.9.4). In TechnoGIN results, outcomes will show the values per 50kg of bag so the amount of farm yard manure used will be multiplied by four times and amount of vermicompost used will be multiplied by two.

Table 2.14 % Nutrient concentration in different fertilizers used in Karnataka.

Sr.no	Name of fertilizer	%N	%P	%K
1	Urea	46	0	0
2	Di- ammonium phosphate	18	20.24	0
3	10-26-26	10	10.4	26
4	Farm Yard Manure	0.3	0.066	0.4
5	Vermicompost	0.6	0.59	0.8
6	Poultry Manure	1.8	1.8	0.8
7	20-20-0	20	20	0
8	Muriate of Potash	0	0	60

2.11.3 N, P and K efficiency (Rorg/Rmin)

The nutrient supply efficiency is set to 1.0 as the chemical fertilizers are inorganic so there is no problem of mineralization. While in organic fertilizer the value mentioned in previous column are N, P and K availability in the manure after mineralization, so the efficiency in the organic fertilizer are also set to 1.0.

2.11.4 Prices per 50 kg bag dry matter

Fertilizers in India are always available in the package of 50 kg bag except farm-yard manure and vermicompost. So prices are set per bag of any considered nutrients. The prices of farm yard manure are set to 240 per 200kg of bag and vermicompost 200 per 100kg of bag. The chemical fertilizers are highly subsidized by the Indian government, so the price remained the same in spite of increasing oil and petrochemical prices in the world market since 3 years. The prices of fertilizer were collected from fertilizer wholesaler and agro-clinics in the market.

2.12 Currency sheet

The sheet contains a matrix with conversion factors of different currencies in different years (Ponsioen et al., 2003). We are considering only three currencies which are Dollar $, Euro € and INR (Indian Rupee). There was much fluctuation in the year 2008 and 2009 due to recession occurred worldwide and also in India. The Indian rupee is the only currency used for model input and output, and in 2008 1 rupee was €0.015 Euros, and $0.025.

2.13 Nutrient sheet

This Nutrient sheet includes data that are used to calculate nutrient inputs and outputs in different parts of the land use systems. Most parameters are related to the texture of the soil as defined in the land management unit sheet, and aerobic or anaerobic conditions in the field as defined in the crop sheet. The data of the apparent nutrient recovery fraction of nitrogen are taken from the field experiments done in the International Crop Research Institute for Semi-Arid Tropics (ICRISAT), Hyderabad. The soil (Alfisols) used in the field experiments is the same as found in the areas of the Chitradurga and Mysore of Karnataka. The experiment shows that the apparent recovery fraction of Nitrogen in aerobic conditions is 50% (Harmsen and Moraghan, 1988). Based on this we assume 45% recovery fraction in total in the farmer fields as the farmer fields are less fertile and there are no optimal application methods. The apparent recovery fraction is calculated from amounts of nitrogen taken up by the crops in unfertilized plots (NP_0) and fertilized plots (NP) and the amount of the fertilizer – nitrogen applied (NF):

$$ARF = (NP - NP0) / NF$$

All the amounts of nitrogen are expressed in kilograms of N per hectare (Harmsen and Moraghan, 1988). For rice in anaerobic conditions they used the same methods in their second experiment for getting the apparent recovery fraction. For phosphorous and potassium the data were taken from the literature of Srinivasrao et al (2003). The parameters are present in the sheet rows and will be explained further

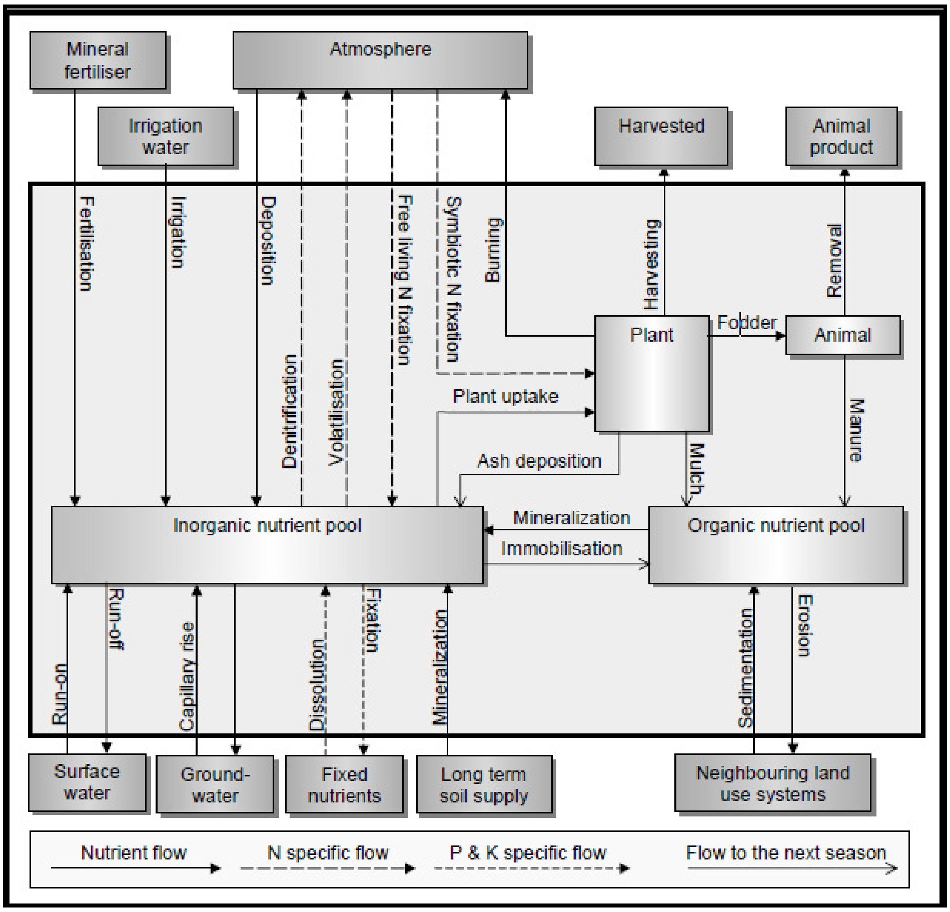


Fig 2.3. Nutrient flow diagram (Ponsioen et al., 2003).

2.13.1 Nitrogen loss fraction

Rows 6-23 are the parameters of nitrogen loss fractions. The total nitrogen loss fraction by nitrogen leaching and volatilization under aerobic conditions was set to 0.55 (Harmsen and Garabet, 2003). The nitrogen loss by volatilization in nutrient sheet was kept 0 due to absence of sufficient data. Hence, all N loss is included under nitrogen leaching, although some of this may be lost through volatilization and denitrification.

The N loss fraction under anaerobic condition was also derived from Harmsen et al. (1988) and we assume total N loss would be 0.7 in the paddy field in anaerobic condition. The fraction of N loss by volatilization and denitrification is set to 0 due to lack of data, and all loss is again included under nitrogen leaching.

2.13.2 Phosphorous loss fraction

Rows 24-28 denote P loss fraction. There is only one parameter of phosphorous loss which is P fixing fraction. The value in this parameter is set to 0.70 which was derived from Srinivasrao et al. (2003).

2.13.3 Potassium loss fraction

Rows 29-42 denote potassium loss fractions by leaching and fixing. The value of K leaching has been set to the default value of 0 in aerobic conditions, and in anaerobic conditions the value of K fixation is set to 0.30 (Srinivasrao et al., 2003).

2.13.4 Nutrient recycling

Rows 43 to 60 denote the parameters of nutrient recycling and contain the nutrient (N, P and K) fraction burn losses, fraction of consumed fodder that is removed in animal product, immobilization and mineralization. Default values are used with 80%, 0% and 0% loss of respectively N, P and K in burnt residues, 20% of consumed fodder removed in animal products and other 80% can be returned back to the nutrient recycling. Standard values are used in the immobilization and mineralized relative nutrient efficiency (see fig 2.3).

2.13.5 Nutrient inflows

The data of N, P and K deposition (Table 2.15) are derived from the book written by Sreerangappa et al (1999). The N concentration in irrigation is 0.000045 kg/l and is derived from the database published by the central ground water board, ministry of water resource, Government of India (Anonymous, 2009k). The other parameters such as sedimentation, capillary rise, dissolution of fixed nutrients are set to value 0. The values which are mentioned in run-off (kg/ha) are the values of loss of nutrient due run off by soil erosion. Normally there are 20-40 tons of soil erosion per hectare per year in both district Chitradurga and Mysore (NBSS, Bengaluru, pers. comm., 2009; Sreerangappa et al., 1999). Long term nutrient supply of each soil is already mentioned in the land management unit sheet

Table 2.15 Annual values of N, P and K kg/ha deposition by Sreerangappa et al. (1999).

Deposition by nutrient	Deposition (kg/ha)
Nitrogen deposition	0.14
Phosphorus deposition	0.03
Potassium deposition	0.1

2.13.6 Other losses

Other losses contain nutrient losses in kg/ha due to run off mainly by soil erosion. As mentioned earlier the data has been derived from NBSS, Bengaluru (pers. comm., 2009) and Sreerangappa et al. (1999).

2.13.7 Recovery fraction boundaries

Based on literature review and consultation with the experts, the recovery fraction boundaries were set between 0.2 and 0.6 but for potassium boundaries were set between 0.2 and 0.8. It makes sure that not all nutrients from the fertilizer are lost at extremely high application and efficiency doesnot become 100% at low fertilizer applications.

2.13.8 Water balance

In this there are two parameters 1) Crop coefficient for fallow: crop coefficient value for evapo-transpiration from fallow land is set to a default value of 0.2, representing the soil evaporation and thus minimum Kc value. 2) Extra water loss in anaerobic systems (mm/dekad): It is set to default value of 14.33mm per 10 days. When you look at crop duration of rice it is 140 days so in total the extra water loss is equal to 14*14.33 which is approximately 200 mm per crop per season.

3. Results

As illustrated in the previous Chapter, inputs of TechnoGIN are data on relevant plant and soil processes and other factors describing the production process. The outputs of TechnoGIN are the technical coefficients that describe input-output relationships of crop production systems.
The following technical coefficients are produced.

- Monthly evapotranspiration.
- Monthly labour requirements.
- Fertilizer requirements, nutrient balances and nitrogen loss.
- Purchased bags of fertilizers (fertilizer cost model output).
- Biocide use and index.
- Economic indicators.
- Current fertilizer applications per crop.
- Recovery fractions per season.
- Nitrogen cycling components.
- Phosphorous cycling components.
- Potassium cycling components.

Here we present these outputs in the context of our research questions, comparing organic and conventional systems in two districts, 1) Chitradurga: a) red soil, b) black soil and 2) Mysore, red soil. First, socio-economic and ecological indicators of conventional and organic systems in the current (2008) and future (2015) situation are presented. Subsequently, scenarios for improved nutrient management are presented.

3.1 Economic indicators

Economic indicators are evaluated to compare the profits and costs of conventional and organic crop rotation. These indicators include fertilizer costs, labour costs, other costs and gross profit, resulting in the net profit.

3.1.1 Fertilizer costs

Table 3.1 and 3.2 present the comparison between fertilizer costs of farmers in Mysore and Chitradurga in the current situation (technology A, C) according to optimization of fertilizer types by TechnoGIN (1st and 3rd column) and according to own calculations based on actual data of fertilizer types used (2nd and 4th column), in both conventional and crop rotations (see section 2.3 for more explanation). In Chitradurga, fertilizer costs are lower for all organic crop rotations compared to conventional ones. The model shows more optimal and lower costs of fertilizers than the actual data, so there is room for improvements in the nutrient application from different fertilizer types. The farmers are applying fertilizers without knowing the potential supply of nutrients from any fertilizer type, but the model results suggest that the nutrients can be applied by other fertilizer types in a more efficient way. In the following table the light blue colour shows the best option of conventional or conventional if fertilizer types are optimized according to TechnoGIN. The green colour shows the best option of conventional or organic in terms of minimum fertilizer costs, based on what is currently applied according to the data

Table 3.1 Comparison of fertilizer cost in INR (Indian Rupees) for different crop rotations in Chitradurga calculated in TechnoGIN and actual application. The costs of own farm yard manure and/or vermicompost are subtracted from the total costs. The best option, organic or conventional, is in colour.

Crop rotation	Conv TechnoGIN	Conv Actual	Org TechnoGIN	Org Actual
Maize- Sunflo	7,051	9,276	180	684
Ragi-Gnut	7,051	9,276	180	684
Ragi-Maize-Sunflo	7,051	9,276	180	684
Ragi-Maze-Gnut	8,797	13,736	720	1,116
Sunflo-Maize	7,051	9,276	180	684
Sunflo-Maize-Gnut	8,797	13,736	720	0
Sunflo-Ragi-Gnut	8,797	6,848	0	0
Sunflo-Ragi	7,051	9,276	0	0
Maize-Ragi	7,051	9,276	0	0
Onion-Maize-Sunflow	9,906	9,888	0	3,612
Onion-Ragi- Gnut	11,652	14,900	660	2,250
Onion-Ragi-Sunflow	9,905	14,348	4,260	2,250
Onion-Maize-Gnut	11,652	14,900	0	4,050
Gnut-Ragi	7,051	9,276	0	0
Gnut-Maize	7,051	9,276	180	684
Onion-Sunflo	9,906	9,888	1,320	2,064
Onion-Ragi	9,906	9,888	0	2,250
Maize-Gnut	7,051	9,276	180	684

The results for Mysore are not as straightforward as for Chitradurga. According to TechnoGIN, if the farmers would apply fertilizers optimally, costs for organic cropping would be lower except for sugarcane and coconut. In the actual situation however, fertilizer costs in organic cropping is only lower for coconut, crop rotation with tur-lentil and crop-rotations with only 2 seasons. Especially in crop rotations with 3 seasons too much nutrients are applied, and hence costs too high.

Table 3.2 Comparison of fertilizer cost in INR (Indian Rupees) for different crop rotation in Mysore calculated in TechnoGIN and actual application. The costs of own farm yard manure and/or vermicompost are subtracted from the total costs.

Crop rotation	Conv TechnoGIN	Conv Actual	Org TechnoGIN	Org Actual
Sugarcane	5,670	4,988	15,600	9,000
Coconut	980	4,906	6,300	4,500
Rice-Cowpea-Sesame	6,460	5,548	2,160	7,200
Rice-Cowpea-Rice	7,545	6,602	4,320	8,100
Rice-Cowpea	4,825	4,068	2,160	3,600
Rice-Ragi-Rice	7,075	6,548	4,320	8,100
Cotton-Cowpea-Sesame	8,200	5,448	0	6,300
Cotton-Cowpea-Rice	6,775	6,502	2,160	7,200
Cotton-Cowpea	4,055	3,968	0	2,700
Cotton-Ragi-Rice	6,305	5,548	2,160	7,200
Tur-Lentil-Cowpea-Sesame	3,740	3,014	0	2,700
Tur-Lentil-Cowpea-Rice	4,825	4,068	2,160	3,600
Tur-Lentil-Cowpea	2,105	1,534	0	0
Tur-Lentil-Ragi-Rice	4,355	4,014	2,160	3,600
Cowpea-Ragi-Rice	6,305	5,548	2,160	7,200
Cowpea-Ragi	3,585	3,014	0	2,700
Ragi-Cowpea-Rice	6,460	5,548	2,160	7,200
Ragi-Cowpea	3,740	3,014	0	2,700

Table 3.1 and 3.2 clearly indicate there is a difference in fertilizer costs between conventional and organic, and that this depends on the crop rotation. Table 3.3 and 3.4 show that if the Karnataka state government policy of producing vermicompost is not implemented properly, the cost of fertilizers will increase. This is because farmers will depend on 15 tons of manure which is not sufficient for crop production. Especially for crops like sugarcane, rice and onion it would be more costly. These tables also show that TechnoGIN recommends more application of vermicompost, as nutrient availability per rupee investment is more than farm yard manure. Table 3.3 and 3.4 clearly indicate how the fertilizer costs increases if farmers don’t have their own vermicompost. When efficiency is compared, chemical fertilizer is more efficient than organic fertilizer. It would cost less than organic farming especially for the crops like sugarcane, rice, cotton and onion in Mysore and Chitradurga.

Table 3.3 Comparison of fertilizer cost in INR (Indian Rupees) for different crop rotation considering availability of only organic manure (FYM) and no vermicompost in Chitradurga. Extra nutrients need to be applied by buying fertilizers.

Crop rotation	If only considering FYM in Conv TechnoGIN	If only considering FYM in Conv Actual	If only considering FYM in Org TechnoGIN	If only considering FYM in Org Actual
Maize- Sunflo	17,431	13,356	12,000	5,580
Ragi-Gnut	17,431	13,356	12,000	5,580
Ragi-Maize-Sunflo	17,431	13,356	12,000	5,580
Ragi-Maze-Gnut	19,177	17,816	15,600	8,460
Sunflo-Maize	17,431	13,356	12,000	5,580
Sunflo-Maize-Gnut	19,177	17,816	15,600	8,460
Sunflo-Ragi-Gnut	19,177	8,888	9,600	4,320
Sunflo-Ragi	17,431	13,356	6,000	1,440
Maize-Ragi	17,431	13,356	6,000	1,440
Onion-Maize-Sunflow	20,286	11,928	10,800	6,740
Onion-Ragi-groundnut	22,032	18,980	8,100	4,580
Onion-Ragi-Sunflow	20,285	16,388	11,700	9,620
Onion-Maize-Gnut	22,032	18,980	7,200	2,600
Gnut-Ragii	17,431	13,356	6,000	1,440
Gnut-Maize	17,431	13,356	12,000	5,580
Onion-Sunflo	20,286	11,928	10,800	6,740
Onion-Ragi	20,286	11,928	7,200	2,600
Maize-Gnut	17,431	13,356	12,000	5,580

Table 3.4 Comparison of fertilizer cost in INR (Indian Rupees) for different crop rotation considering availability of only organic manure and no vermicompost in Mysore. Extra nutrients need to be applied by buying fertilizers.

Crop rotation	If only considering FYM in Conv TechnoGIN	If only considering FYM in Conv Actual	If only considering FYM in Org TechnoGIN	If only considering FYM in Org Actual
Sugarcane	5,670	4,988	41,100	33,300
Coconut	980	4,907	6,300	4,500
Rice-Cowpea-Sesame	6,460	5,548	32,000	27,600
Rice-Cowpea-Rice	7,545	6,602	34,000	33,600
Rice-Cowpea	4,825	4,068	22,000	18,900
Rice-Ragi-Rice	7,075	6,548	34,000	33,600
Cotton-Cowpea-Sesame	8,200	5,448	30,000	21,600
Cotton-Cowpea-Rice	6,775	6,502	32000	27,600
Cotton-Cowpea	4,055	3,968	20,000	12,900
Cotton-Ragi-Rice	6,305	5,548	32,000	27,600
Tur-Lentil-Cowpea-Sesame	3,740	3,014	20,000	12,900
Tur-Lentil-Cowpea-Rice	4,825	4068	22,000	18,900
Tur-Lentil-Cowpea	2,105	1,534	10,000	4,200
Tur-Lentil-Ragi-Rice	4,355	4,014	22,000	18,900
Cowpea-Ragi-Rice	6,305	5,548	32,000	27,600
Cowpea-Ragi	3,585	3,014	20,000	12,900
Ragi-Cowpea-Rice	6,460	5,548	32,000	27,600
Ragi-Cowpea	3,740	3,014	20,000	12,900

Whether vermicompost is available or not, the fertilizer costs of Mysore are lower in conventional land use types compared to organic (Table 3.2 and 3.4). Excluding the costs of own farm yard manure had no effects on conventional land use types, which means that farmers in conventional land use types don't use farm yard manure and that Mysore is a high chemical fertilizer input area. Therefore, the vermicompost also does not affect the costs of conventional types. The fertilizer costs in organic land use types when excluding availability of vermicompost increases more than 3 times. Organic is thus not cheaper in Mysore, because of high nutrient requirements of crops growing in this area which needs more amount of farm yard manure. On the opposite, in Chitradurga (Table 3.1 and 3.3), the fertilizer costs in organic farming is cheaper, even when vermicompost is not available because fertilizers applied in the different crop rotation of Chitradurga is lower than Mysore. Due to low fertilizer input the cost of fertilizer will be lower in organic than conventional. Here farmers having conventional farming methods also use farm yard manure. This farm yard manure is collected in their pits and used in their own farm. Chitradurga is a low fertilizer input area and organic crop rotation will have lower costs of fertilizer than conventional because available farm yard manure and vermicompost is sufficient for farmers to apply in the field.

3.1.2 Monthly labour requirements

Labour required for land preparation, crop establishment (sowing or planting), crop management (fertilizer application, crop protection, etc) and harvesting has been calculated with TechnoGIN. Here the main purpose was to see the result of labour requirement difference between the organic and conventional methods of farming in both of districts Chitradurga and Mysore. As mentioned in the crop sheet, the farms in Karnataka are not well mechanized and use few technologies due to small and fragmented land holdings. Labour required in conventional and organic farms are the same. Farmers don't use herbicides in their farm, while labour required for broadcasting fertilizer and pesticide application in conventional farms are equal to labour required in organic farms for manure application. Hand weeding and inter-culturing are done both in organic and conventional farms. There is difference in labour days in harvesting crop as the yields are not similar in organic and conventional farming.

Table 3.5 Results of labour days required in different months for every crop rotation of conventional and organic farming in 2008 and 2015 in Chitradurga.

Crop rotation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maize-Sunflower Conventional	12	9	0	0	0	49	3	3	145	10	13	4
Maize-Sunflower Organic	12	9	0	0	0	49	3	3	103	10	13	4
Ragi-Groundnut Conventional	30	0	0	0	0	21	3	3	32	12	20	6
Ragi-Groundnut Organic	28	0	0	0	0	21	3	3	20	12	20	6
Ragi-Maize-Sunflower Conventional	3	143	13	4	11	19	3	3	32	27	23	3
Ragi-Maize-Sunflower Organic	3	223	13	4	8	16	3	3	20	27	23	3
Ragi-Maize-Groundnut Conventional	3	145	20	6	18	21	3	3	32	27	23	3
Ragi-Maize-Groundnut Organic	3	225	20	6	19	21	3	3	20	27	23	3
Sunflower-Maize Conventional	3	133	0	0	0	21	4	4	19	27	23	3
Sunflower-Maize Organic	3	213	0	0	0	21	4	4	23	27	23	3
Sunflower-Maize-Groundnut Conventional	3	145	20	6	18	21	4	4	19	27	23	3
Sunflower-Maize-Groundnut Organic	3	225	20	6	19	21	4	4	23	27	23	3
Sunflower-Ragi-Groundnut Conventional	3	43	20	6	18	21	4	4	19	10	12	3
Sunflower-Ragi-Groundnut Organic	3	33	20	6	19	21	4	4	23	10	12	3
Sunflower-Ragi Conventional	3	31	0	0	0	21	4	4	19	10	12	3
Sunflower-Ragi Organic	3	21	0	0	0	21	4	4	23	10	12	3
Maize-Ragi Conventional	3	30	0	0	0	49	3	3	145	10	12	3
Maize-Ragi Organic	3	21	0	0	0	49	3	3	104	10	12	3
Onion-Maize-Sunflower Conventional	3	143	13	4	11	44	2	2	24	27	23	3
Onion-Maize-Sunflower Organic	3	223	13	4	8	41	2	2	15	27	23	3
Onion-Ragi-Groundnut Conventional	3	43	20	6	18	76	2	2	24	10	12	3
Onion-Ragi-Groundnut Organic	3	33	20	6	19	76	2	2	15	10	12	3
Onion-Ragi-Sunflower Conventional	3	41	13	4	11	44	2	2	24	10	12	3
Onion-Ragi-Sunflower Organic	3	31	13	4	8	41	2	2	15	10	12	3
Onion-Maize-Groundnut Conventional	3	145	20	6	18	76	2	2	24	27	23	3
Onion-Maize-Groundnut Organic	3	225	20	6	19	76	2	2	15	27	23	3
Groundnut-Ragi Conventional	3	31	0	0	0	30	6	6	24	10	12	3
Groundnut-Ragi Organic	3	21	0	0	0	30	6	6	39	10	12	3
Groundnut-Maize Conventional	3	133	0	0	0	30	6	6	24	27	23	3
Groundnut-Maize Organic	3	213	0	0	0	30	6	6	39	27	23	3
Onion-Sunflower Conventional	12	9	0	0	0	76	2	2	24	10	13	4
Onion-Sunflower Organic	12	9	0	0	0	76	2	2	15	10	13	4
Onion-Ragi Conventional	3	31	0	0	0	76	2	2	24	10	12	3
Onion-Ragi Organic	3	21	0	0	0	76	2	2	15	10	12	3
Maize-Groundnut Conventional	28	0	0	0	0	49	3	3	146	12	20	6
Maize-Groundnut Organic	28	0	0	0	0	49	3	3	104	12	20	6

In Chitradurga, maize crops have the highest number of labour required for the crop production (see also Table 2.2). For maize in rabi, it increases with organic methods because yield in organic systems is more than conventional, and labour requirements for harvesting are calculated in tons per hectare. In both cases, the labour requirement is more than 100 labour days at that period which can affect overall availability of labour in that period of that region.

Table 3.6 Results of labour days required in different months for every crop rotation of conventional and organic farming in 2008 and 2015 in Mysore.

Crop rotation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sugarcane Conventional	3	3	3	3	202	57	3	3	3	3	3	3
Sugarcane Organic	3	3	3	3	194	57	3	3	3	3	3	3
Coconut Conventional	0	0	0	0	35	33	0	0	0	0	0	0
Coconut Organic	0	0	0	0	30	33	0	0	0	0	0	0
Rice-Cowpea-Sesame Conventional	4	21	13	4	8	73	3	3	3	38	13	4
Rice-Cowpea-Sesame Organic	4	18	13	4	8	73	4	4	4	24	18	4
Rice-Cowpea-Rice Conventional	4	59	26	3	3	3	32	3	3	38	13	4
Rice-Cowpea-Rice Organic	4	56	27	4	4	4	16	4	4	24	18	4
Rice-Cowpea Conventional	4	10	0	0	0	73	3	3	3	38	13	4
Rice-Cowpea Organic	4	8	0	0	0	73	4	4	4	24	18	4
Rice-Ragi-Rice Conventional	3	64	26	3	3	3	32	3	3	38	12	3
Rice-Ragi-Rice Organic	3	69	27	4	4	4	16	4	4	24	12	3
Cotton-Cowpea Conventional	4	21	13	4	8	31	4	4	4	67	13	4
Cotton-Cowpea Organic	4	18	13	4	8	31	4	4	4	25	18	4
Cotton-Cowpea-Rice Conventional	4	59	26	3	3	3	32	4	4	67	13	4
Cotton-Cowpea-Rice Organic	4	56	27	4	4	4	16	4	4	25	18	4
Cotton-Cowpea Conventional	4	11	0	0	0	31	4	4	4	67	13	4
Cotton-Cowpea Organic	4	8	0	0	0	31	4	4	4	25	18	4
Cotton-Ragi-Rice Conventional	3	64	26	3	3	3	32	4	4	67	12	3
Cotton-Ragi-Rice Organic	3	69	27	4	4	4	17	4	4	25	12	3
Tur-lentil-Cowpea-Sesame Conventional	4	21	13	4	8	21	3	3	3	12	13	4
Tur-lentil-Cowpea-Sesame Organic	4	18	13	4	8	21	3	3	3	12	18	4
Tur-lentil-Cowpea-Rice Conventional	4	59	26	3	3	3	5	3	3	12	13	4
Tur-lentil-Cowpea-Rice Organic	4	56	27	4	4	4	15	3	3	12	18	4
Tur-lentil-Cowpea Conventional	4	11	0	0	0	21	3	3	3	12	13	4
Tur-lentil-Cowpea Organic	4	8	0	0	0	21	3	3	3	12	18	4
Tur-lentil-Ragi-Rice Conventional	3	64	26	3	3	3	31	3	3	12	12	3
Tur-lentil-Ragi-Rice Organic	3	69	27	4	4	4	15	3	3	12	12	3
Cowpea-Ragi-Rice Conventional	3	64	26	3	3	3	32	4	13	10	12	3
Cowpea-Ragi-Rice Organic	3	69	27	4	4	4	16	4	9	10	12	3
Cowpea-Ragi Conventional	3	16	0	0	0	21	4	4	13	10	12	3
Cowpea-Ragi Organic	3	21	0	0	0	26	4	4	9	10	12	3
Ragi-Cowpea-Rice Conventional	4	59	26	3	3	3	32	3	44	10	13	4
Ragi-Cowpea-Rice Organic	4	56	27	4	4	4	16	3	30	10	18	4
Ragi-Cowpea Conventional	4	11	0	0	0	21	3	3	44	10	13	4
Ragi-Cowpea Organic	4	8	0	0	0	21	3	3	30	10	18	4

In Mysore, sugarcane has the highest number of labour days required for the crop production, as labour requirement for harvesting is very high because air-dry production of sugarcane crop is more than any other crop. Labour requirement for harvesting sugarcane crop is a constraint due to low labour availability at that period. There is no significant difference between organic and conventional organic methods in labour requirements.

3.1.3 Net Profit

TechnoGIN calculates the amount of the gross income or returns coming from the production by multiplying farm gate price per kg with production in kg/ha. The gross income or returns are corrected with cost of fertilizer, labour cost, biocide cost and other cost. The other costs are seed cost and animal cost. The seed costs, animal costs and labour costs for land preparation, crop management and crop establishment were the same for organic and conventional crop rotation. There are no biocide costs for organic farming. Hence, the differences in costs are in actual fertilizer costs (as presented in 3.1.1) in both conventional and organic farming, labor costs for harvesting (depending on yields as explained in 3.1.2) and biocide costs (none for organic).

In Chitradurga profit is higher in organic than conventional farming in both 2008 and 2015, except ragi-groundnut, maize- ragi and crop rotations having onion as crop in the rotation. The yield of these crops is higher in conventional than organic farming which make them more profitable. This demonstrates that cash crops like onion, kharif maize, rabi groundnut which are high input crops, are still more profitable in conventional farming. The difference between the profit in organic and conventional 2015 farming is large (Table 3.7). It clearly shows that 30% premium price on organic products makes a difference in having profit from different organic crop rotation in 2015. Even some onion rotations can obtain higher profits when going organic.

Table 3.7 Results and comparison of profit in conventional and organic crop rotations in 2008 and 2015 in Chitradurga. The systems with highest profits are in colour, both for 2008 and 2015.

	Profit Conventional		**Profit Organic**	
Crop rotation	**2008**	**2015**	**2008**	**2015**
Maize- Sunflo	33,556	45,806	36,049	68,987
Ragi-Gnut	39,417	50,808	35,238	61,103
Ragi-Maize-Sunflo	49,029	65,479	51,739	98,704
Ragi-Maze-Gnut	33,772	44,089	50,000	93,200
Sunflo-Maize	30,132	40,578	58,801	110,622
Sunflo-Maize-Gnut	37,188	48,947	72,749	133,835
Sunflo-Ragi-Gnut	52,866	69,547	61,167	110,120
Sunflo-Ragi	38,922	54,290	47,793	87,387
Maize-Ragi	27,556	36,698	23,368	44,808
Gnut-Ragi	36,429	47,309	52,776	91,277
Gnut-Maize	22,627	28,584	65,720	116,354
Onion-Maize-Sunflo	120,547	152,486	98,148	173,193
Onion-Ragi-Gnut	115,737	145,266	81,209	139,156
Onion-Ragi-Sunflo	134,408	171,271	88,816	151,727
Onion-Maize-Gnut	112,571	137,178	96,157	166,237
Onion-Sunflo	114,137	145,094	83,406	143,680
Onion-Ragi	109,233	137,449	69,635	118,223
Maize-Gnut	28,828	34,942	32,446	58,043

Considering debts when crop failure occurs in Chitradurga, the green strips in Table 3.8 indicate that organic farmers always have lower debts than conventional farmers in both scenarios 2008 and future 2015. In 2015, the inputs and labour costs increase so farmers may go more in debt if the crops fail. Most farmers in Chitradurga have crop rotations with two crops, but these are more prone to drought and pest incidences as compared to Mysore. But reduced cost of fertilizer due to supplying own vermicompost to their own farm can decrease cost of buying fertilizers from outside and thus increase the profit of land use types.

Table 3.8 Result and comparison of debts of farmer in conventional and organic crop rotations in Chitradurga. Both for 2008 and 2015, the option with least debts is in colour.

	Loss Conventional		**Loss Organic**	
Crop rotation	**2008**	**2015**	**2008**	**2015**
Maize- Sunflo	-18630	-22312	-9659	-13156
Ragi-Gnut	-18088	-21878	-8988	-12418
Ragi-Maize-Sunflo	-21769	-27384	-11579	-15916
Ragi-Maze-Gnut	-27511	-33673	-14295	-20048
Sunflo-Maize	-20089	-25056	-9659	-13156
Sunflo-Maize-Gnut	-30457	-37860	-14609	-20295
Sunflo-Ragi-Gnut	-20985	-27125	-12404	-17007
Sunflo-Ragi	-17505	-21209	-6770	-9183
Maize-Ragi	-17172	-20912	-7545	-11109
Gnut-Ragi	-18740	-22490	-11956	-15346
Gnut-Maize	-26296	-31349	-12759	-17272
Onion-Maize-Sunflo	-30380	-37189	-15775	-20872
Onion-Ragi- Gnut	-31879	-39174	-19904	-26534
Onion-Ragi-Sunflo	-22724	-28270	-11320	-15333
Onion-Maize-Gnut	-28840	-37396	-18743	-26456
Onion-Sunflo	-22418	-27218	-13714	-18087
Onion-Ragi	-20960	-25818	-12470	-16910
Maize-Gnut	-20701	-25769	-11193	-15706

Mysore has several cash crops like sugarcane, rice and cotton. Table 3.9 clearly indicates that these crops are more profitable in conventional than organic farming. Also for 2015, profits of most organic crop rotation are expected to be lower than for conventional land use types. The reason is the lower yields in organic farming, and that the higher biocide costs in conventional farming are compensated by higher crop yields. These crops are more prone to pest and disease attacks which reduced yield a large extent. Crops like tur-dal, cowpea and ragi are traditional crops and not cultivated for profits. When the profits in the current situation are compared, there is a large difference in income between conventional and organic, but in 2015 the profits are almost the same. This is because of more net profit due to 30% premium value for organic crops.

Table 3.9 Results and comparison of net profit in conventional and organic crop rotations in 2008 and 2015 in Mysore. Both for 2008 and 2015, the option with highest profit is in colour.

	Profit Conventional		Profit Organic	
Crop rotation	**2008**	**2015**	**2008**	**2015**
Sugarcane	35,280	35,182	34,560	37,240
Coconut	38,599	35,659	34,995	32,279
Rice-Cowpea-Sesame	58974	80,584	35,965	74,939
Rice-Cowpea-Rice	72,438	98,790	36,561	77,701
Rice-Cowpea	47,473	66,390	28,066	58,726
Rice-Ragi-Rice	46,494	60,510	24,634	52,941
Cotton-Cowpea-Sesame	83,795	10,5803	38,992	77,976
Cotton-Cowpea-Rice	96,184	12,1275	36,438	75,907
Cotton-Cowpea	69,868	89,183	31,094	61,763
Cotton-Ragi-Rice	69,628	56,933	24,511	51,185
Tur-Lentil-Cowpea-Sesame	44,045	64,386	46,091	86,439
Tur-Lentil-Cowpea-Rice	30,985	46,860	42,977	83,099
Tur-Lentil-Cowpea	32,547	50,194	37,292	69,327
Tur-Lentil-Ragi-Rice	37,713	48,395	30,780	58,376
Cowpea-Ragi-Rice	67,995	93,835	38,949	80,753
Cowpea-Ragi	41,834	62,306	33,996	67,210
Ragi-Cowpea-Rice	83,613	11,4293	48,089	97,196
Ragi-Cowpea	58,697	84,021	43,532	84,259

A major reason for the organic policy is to avoid that farmers face debts after several years of crop failure. Table 3.10 demonstrates that if the farmer has lost its yield completely due to drought or sudden pest incidence, then organic will have less debt than conventional farming, except sugarcane. This is because low cost in organic agriculture. But when looked at the difference between debts of organic and conventional farming, the difference is very small both in 2008 and in 2015. Comparing the crop rotation, it should be noted that generally if a farmer lost his two crops in two consecutive seasons, he will not go further for third crop, and poor farmers having 1 ha of land will never go for more than two crops. The high debts for 3 crops will therefore in practice never occur. Table 3.10 also shows crop rotations having two crops. It clearly indicates that rotations with rice, cotton and sugarcane result in more debts than other crop rotations because of higher labour, fertilizer and pesticide inputs.

There is difference in the net profit (Table 3.7 and Table 3.9) and risk of debts (Table 3.8 and 3.10) between two districts Chitradurga and Mysore. Differences are due to the crop rotations practiced in both districts. The crops like rice, sugarcane and cotton in Mysore are high input crops and if the yields are lower than conventional, then obviously profits will be lower. Even the 30% premium price in the year 2015 cannot compensate the loss. In contrast, in Chitradurga organic production is almost similar to conventional farming, while for crops like ragi and maize it is even more than conventional. These crops also require low external inputs, so the profits are higher in organic farming. The 30% premium projected for 2015 further increases the benefits to the farmers.

Table 3.10 Results and comparison of debts of farmers with crop failure in conventional and organic crop rotations in Mysore. Both for 2008 and 2015, the option with least debts is in color.

	Loss Conventional		**Loss Organic**	
Crop rotation	**2008**	**2015**	**2008**	**2015**
Sugarcane	-26,432	-32,530	-28,200	-31,880
Coconut	-94,06.8	-10,946.8	-9,000	-10,540
Rice-Cowpea-Sesame	-22,234	-29,541	-22,450	-28,210
Rice-Cowpea-Rice	-24,628	-32,835	-23,106	-28,059
Rice-Cowpea	-18,024	-24,132	-16,120	-20,680
Rice-Ragi-Rice	-22,745	-31,021	-21,277	-26,299
Cotton-Cowpea-Sesame	-18,532	-24,645	-17,700	-21,900
Cotton-Cowpea-Rice	-24,035	-32,705	-21,465	-26,516
Cotton-Cowpea	-14,322	-19,235	-11,370	-14,370
Cotton-Ragi-Rice	-21252	-29,954	-19,636	-24,719
TurLentil-Cowpea-Sesame	-12,908	-16,545	-12,594	-16,231
TurLentil-Cowpea-Rice	-17,588	-23,004	-16,919	-22,119
TurLentil-Cowpea	-8,698	-11,135	-7,164	-9,601
TurLentil-Ragi-Rice	-17,357	-24,026	-15,360	-20,322
Cowpea-Ragi-Rice	-20,605	-27,203	-20,674	-25,566
Cowpea-Ragi	-10,125	-12,557	-9,811	-12,243
Ragi-Cowpea-Rice	-20,626	-27,235	-20,694	-25,597
Ragi-Cowpea	-10,125	-12,557	-9,811	-12,243

3.2 Ecological indicators

Ecological indicators refer to externalities of production having impact on the environment. They include monthly evapotranspiration of the field, water requirement, biocide index, N loss and N surplus.

3.2.1. Monthly evapotranspiration and water requirements via irrigation

As mentioned earlier, in India crop cultivation practices depend on the monsoon rainfall. Most of the fields in Mysore and Chitradurga are rain fed. The farmers depend mostly upon the rains as their water source, except the few who have bore-wells in their own farms. Evapotranspiration is calculated by multiplying reference evapotranspiration with crop coefficients (Doorenbos & Pruitt, 1977). Figures 3.1 and 3.2 present the monthly evapotranspiration in Chitradurga and Mysore which are calculated in mm/month. The results show that there are differences in monthly evapotranspiration between different crop rotation and districts, but there is no difference between organic and conventional method of crop cultivation. The result of evapotranspiration also shows the climate in these regions is hot and humid. Evapotranspiration increases in summer, and consequently water requirements also increase in summer. Most farmers prefer not to cultivate in the summer season, due to scarcity of water for irrigation. Land use types with 2 crops only have no cultivation in summer, and evapotranspiration is equal to fallow land.

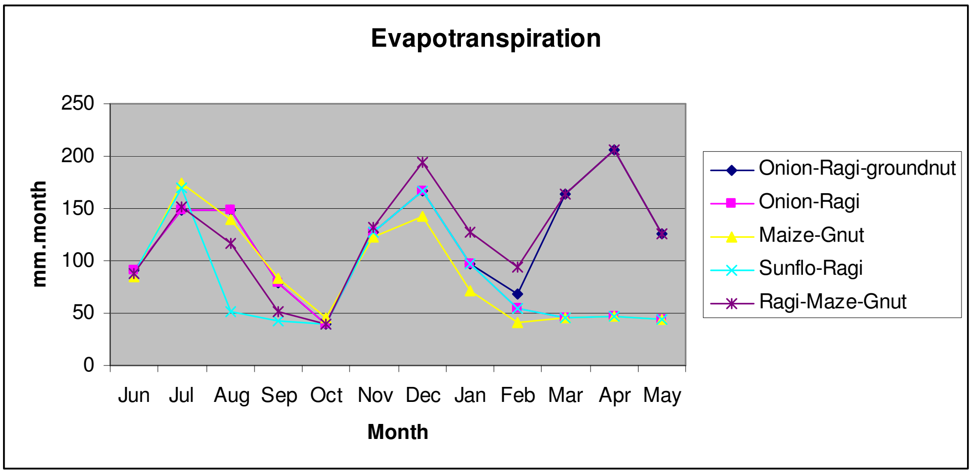


Fig 3.1 Evapotranspiration in mm/month of different land use types in Chitradurga district.

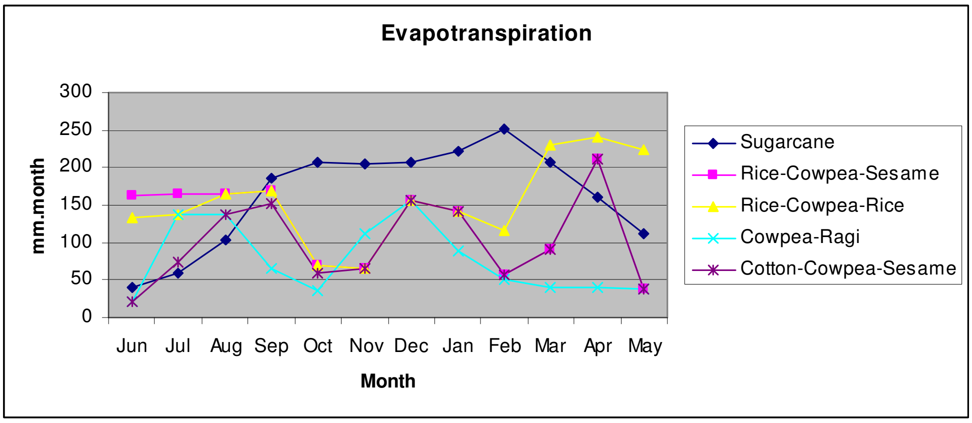


Fig 3.2 Evapotranspiration in mm/month of different land use types in Mysore district.

According to the map of agro-ecological zones of Karnataka, Chitradurga lies in the central dry zone and Mysore in the transition zone. But average rainfall of the last three years in Chitradurga (517 mm/year) is more than Mysore (465 mm/year). Now water requirements are calculated as follows:

Water requirements = Rainfall- actual evapotranspiration-water losses due to puddling and percolation

Water losses due to puddling and percolation are equal to 0 except for rice. Table 3.11 shows that even after rainfall during cropping seasons, there are still water requirements for the crops. This suggests that the rainfall is not adequate for fulfilling the water requirement of the crops in any season. Famers who have irrigation facilities such as bore-wells in their own field can supply irrigated water to the crop, which can boost the yields of the crops, but the farmers who do not have any irrigation facilities can face water stress which can hamper the yields of the crops. This is likely one of the reasons of the low yields in the district of Chitradurga. Chitradurga is considered as a hotspot of depleting ground water resources. There is a tremendous decline in water depth and the water tables were already low (1990-2002 survey). This is mainly due to over-exploitation and poor distribution systems (Anonymous, 2008p).

Generally, Mysore has good canal irrigation facilities, which have ample supply of water throughout the whole year. This helps farmers to have crops like sugarcane, rice and coconut which need a large amount of water (Table 3.12). Crops like ragi, sunflower, groundnut, cowpea and lentil do not require much water and can survive without irrigation facilities (Table 3.11). There are significant differences in water requirements between different cropping seasons such as kharif, rabi and summer for every different crop. For example, groundnut requires 121 mm water in kharif, 207 mm water in rabi and 495 mm in summer season.

Table 3.11 Water requirements (mm/ha) in different cropping seasons in Chitradurga. These are the same for conventional/organic and 2008/2015. Cells of high water intensive LUTs (> 1000 mm/yr) are filled with yellow colour

Land use types	Kharif	Rabi	Summer	Total
Maize- Sunflo	199	221	0	421
Ragi-Gnut	158	207	0	366
Ragi-Maize-Sunflo	158	429	459	1046
Ragi-Maze-Gnut	158	432	495	1087
Sunflo-Maize	158	248	495	903
Sunflo-Maize-Gnut	199	248	495	944
Sunflo-Ragi-Gnut	109	405	0	515
Sunflo-Ragi	109	317	0	427
Maize-Ragi	199	317	0	517
Onion-Maize-Sunflow	190	429	459	1079
Onion-Ragi-groundnut	190	429	459	1079
Onion-Ragi-Sunflow	190	344	495	1031
Onion-Maize-Gnut	190	341	459	991
Gnut-Ragi	190	432	495	1119
Gnut-Maize	119	317	0	437
Onion-Sunflo	190	221	0	413
Onion-Ragi	190	317	0	508
Maize-Gnut	199	207	0	407

Table 3.12 Water requirement mm/ha in different cropping seasons in Mysore. These are the same for conventional/organic and 2008/2015. Cells of high water intensive LUTs (> 1000 mm/yr) are filled with yellow colour.

Land use types	Kharif	Rabi	Summer	Total
Sugarcane	247	761	466	1476
Coconut	385	532	584	1503
Rice-Cowpea-Sesame	643	266	340	1250
Rice-Cowpea-Rice	586	326	695	1609
Rice-Cowpea	643	257	0	901
Rice-Ragi-Rice	586	330	695	1613
Cotton-Cowpea-Sesame	125	266	340	732
Cotton-Cowpea-Rice	254	326	695	1276
Cotton-Cowpea	125	257	0	383
Cotton-Ragi-Rice	254	330	695	1280
TurLentil-Cowpea-Sesame	57	246	340	644
TurLentil-Cowpea-Rice	188	306	695	1191
TurLentil-Cowpea	57	237	0	295
TurLentil-Ragi-Rice	188	283	695	1168
Cowpea-Ragi-Rice	217	276	695	1190
Cowpea-Ragi	126	207	0	333
Ragi-Cowpea-Rice	210	306	695	1212
Ragi-Cowpea	180	237	0	418

3.2.2 Biocide use and index

The Biocide Residue Index (BRI) was calculated by TechnoGIN for every land use type. According to Pathak et al (2001) a BRI value of less than 100 can be designated as safe, whereas a value between 100 and 200 is permissible, but a BRI value more than 200 is unsafe with respect to environmental safety. On organic farms use of biocides is not allowed so it is obvious that BRI value in organic land use types will remain 0. In conventional land use types, farmers use pesticides for protection from pests and diseases and to increase the yields of crops.

In Chitradurga, the BRI value of all crop rotation is below 100 and can be designated as safe so it does not have big environmental impacts (Table 3.13). In Mysore (Table 3.14), BRI values for crop rotations including sugarcane, rice, cotton and cowpea have values till permissible level. These can reach unsafe levels if management is intensified, which can have environmental impacts in the future. In this study, for 2015 we have kept the yield level the same and did not change any efficiency in Technology sheet, so the BRI values do not change for 2015.

Table 3.13 Biocide Residue Index (BRI) values of different LUT in conventional land use types in Chitradurga. For 2015 no changes were assumed.

Land Use Type	BRI
Onion-Sunflower	14
Onion-Ragi	14
Maize-Gnut	16
Onion-Ragi-Sunflower	15
Onion-Maize-Gnut	27
Gnut-Ragi	10
Sunflower-Maize-Gnut	7
Maize-Ragi	6
Onion-Maize-Sunflower	20
Onion-Ragi-Gnut	21
Ragi-Maize-Sunflower	6
Ragi-Sunflower-Gnut	8
Maize-Sunflower	6
Ragi-Gnut	10

Table 3.14 Biocide Residue Index (BRI) values of different LUT in conventional land use types in Mysore. For 2015 no changes were assumed.

Land Use Types	BRI
Sugarcane	74
Rice-Cowpea-Sesame	47
Rice-Cowpea-Rice	100
Rice-Cowpea	47
Rice-Ragi-Rice	100
Cotton-Cowpea-Sesame	60
Cotton-Cowpea-Rice	113
Cotton-Cowpea	60
Cotton-Ragi-Rice	113
Tur lentil-Ragi-Rice	52
Cowpea-Ragi-Rice	52
Ragi-Cowpea-Rice	52

3.2.3 Nutrient loss

Environmental impacts also include the nutrient losses from the different crop rotations. Nutrient losses by leaching to soil and groundwater, and nitrogen emissions to air by denitrification and volatilization are calculated by TechnoGIN. As there was lack of data on specific N loss fractions, we did not distinguish between different pathways of N loss.

In Mysore (Fig 3.3) organic land use types have nitrogen losses half or more than half of conventional farming. Although sugarcane is high input crop, N loss in sugarcane is low as compared to other crops, as most nutrients are taken up due to the high yield. N losses are more than 150 kg having rice in conventional crop rotation (Fig 3.3). Improper timing of mineralization of nitrogen from organic manure has not been taken into account, as no literature was found on this subject for this region.

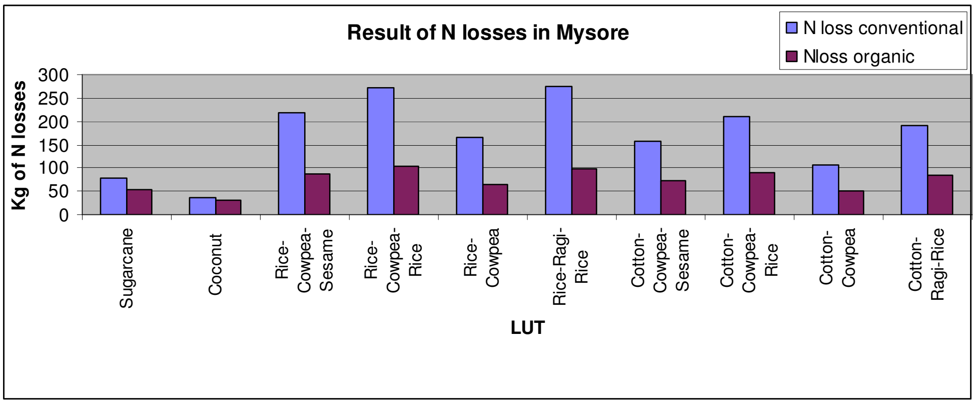


Fig 3.3a Results of total nitrogen losses (kg N/ha/year) in different crop rotations in Mysore.

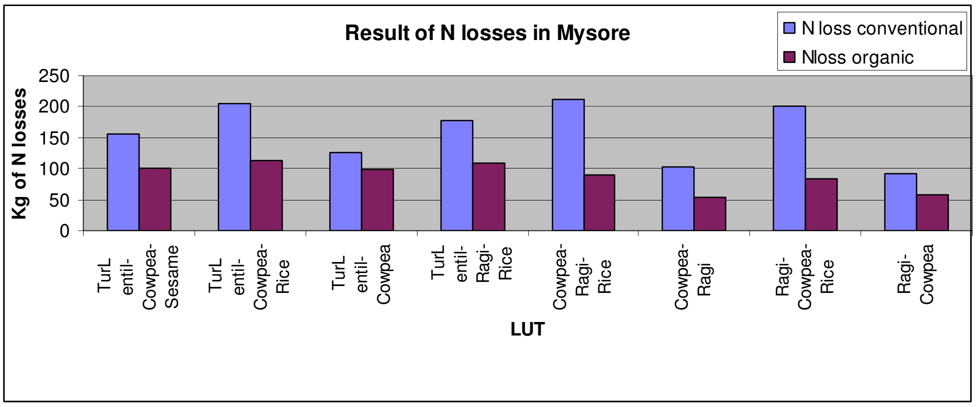


Fig 3.3b Results of total nitrogen losses (kg N/ha/year) in different crop rotations in Mysore.

In Chitradurga (Fig 3.4), results are similar as in Mysore. N loss in conventional is much higher than organic farming. Even if we consider crops like onion, where the application of nutrients in organic is the same as in conventional. The N loss is less than conventional because farmers normally apply less or no fertilizers for the next crop in organic land use types. Especially in organic ragi they do not apply any fertilizer. N losses are more in crop rotations having crops like onion, groundnut and sunflower.

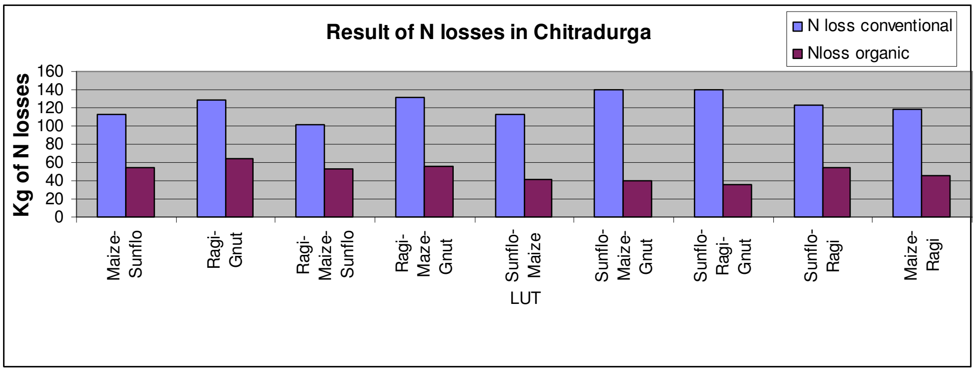


Fig 3.4a Results of nitrogen losses (kg N/ha/year) in different crop rotations in Chitradurga.

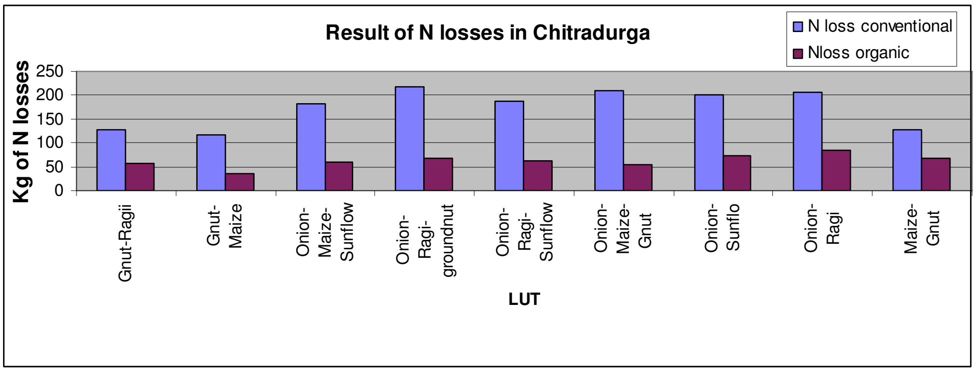


Fig 3.4b Results of nitrogen losses (kg N/ha/year) in different crop rotations in Chitradurga.

3.2.4 Nutrient surplus

The nutrient balance is calculated by subtracting nutrient loss and crop nutrient uptake from the nutrients supplied by fertilizers and soil. Nutrient surplus occurs when not all fertilizers or manure applied are taken up by the crop and it stays in the soil. In the long-term these nutrients can also leach if the time of mineralization and crop uptake is not coherent to each other. If the land is fallow for next season, there are more chances of getting nitrogen leaching. Fig 3.5 depicts the scenario of land use types in Mysore which show higher nutrient surpluses in organic than conventional farming (except in sugarcane). This might be due to low crop yield caused by pest and disease incidence in the field of organic crops. The high nitrogen surplus in conventional land use systems including tur-lentil and cowpea in Fig 3.5b is due to the fertilizer application to the leguminous crops which also fix nitrogen in the soil. Therefore, these do not take up additional nutrients supplied by fertilizers. Land use types having a leguminous crop like tur-lentil and cowpea have more nitrogen surplus both in organic and conventional than land use types not having legumes.

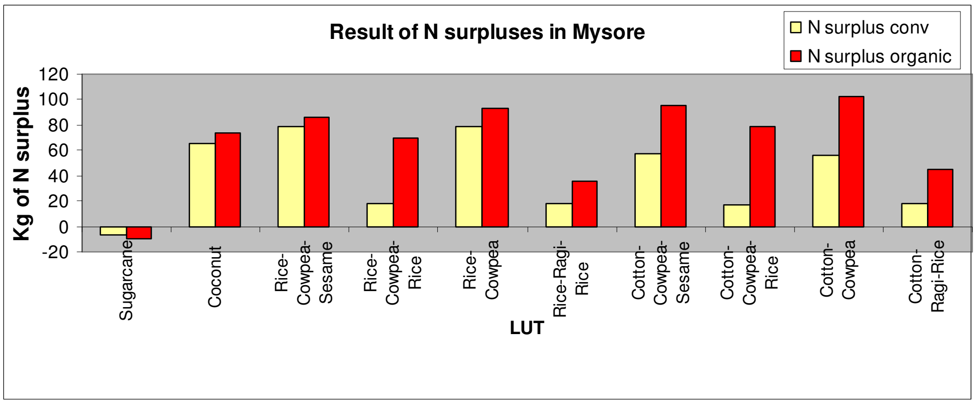


Fig 3.5a Results of nitrogen surplus (kg N/ha/year) in different crop rotations in Mysore.

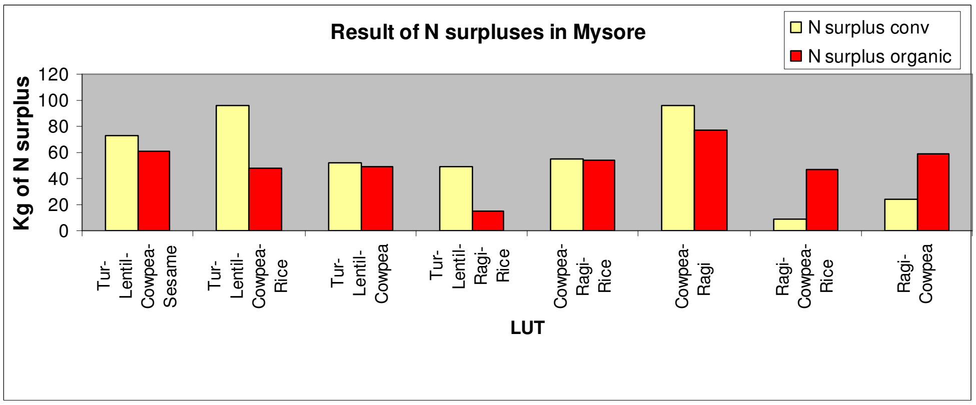


Fig 3.5b Results of nitrogen surplus (kg N/ha/year) in different crop rotations in Mysore.

In case of Chitradurga, the picture is completely opposite of Mysore. (Fig 3.6) The balance of most land use types is negative. It clearly indicates that crop rotations having three crops in Chitradurga may have depletion of nutrients in the long term, especially in organic farming. The reason of the negative balance is that the amount of nutrients applied by the farmers is less than the crop uptake. For example, farmers do not apply any fertilizer to the ragi crop in rabi season and very low amounts of fertilizer to oilseed crops like sunflower and groundnut, but the model calculates the crop uptake by the crop depending on the target yield and nutrient content in the harvested product. The amount of fertilizers applied is not fulfilling the nutrient demand of the crop and that is the reason of the negative balance.

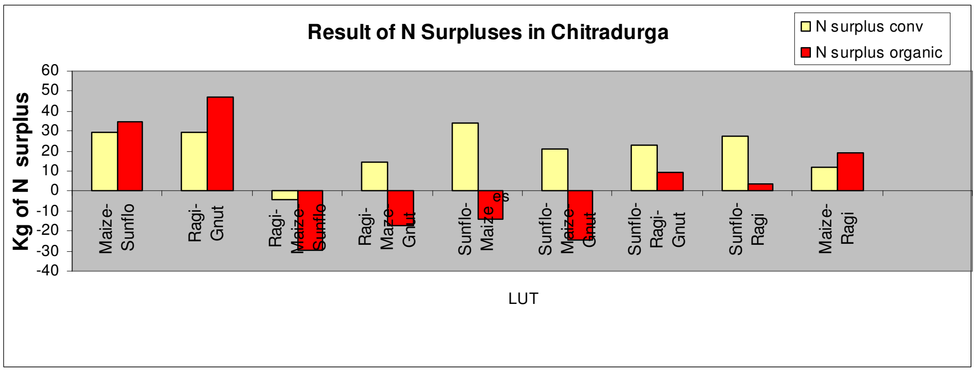


Fig 3.6a Results of nitrogen surplus (kg N/ha/year) in different crop rotations in Chitradurga.

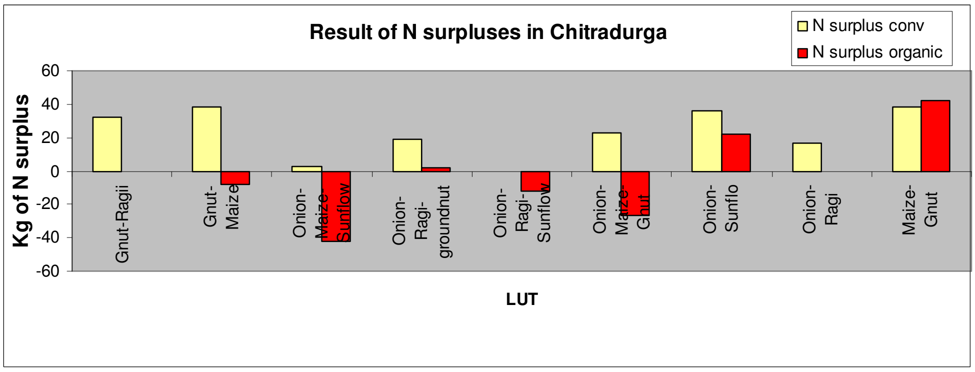


Fig 3.6b. Result of nitrogen surplus (kg N/ha/year) in different crop rotations in Chitradurga.

3.3 Optimizing fertilizer application

Results of fertilizers used in the current actual and future 2015 scenarios are based on the fertilizer gifts mentioned in the Crop sheet (see Table 2.5, 2.6). The fertilizer gifts depend on nutrients present in that fertilizer and nutrient efficiency. It was also estimated how much fertilizers should be used for optimal nutrient management, aiming for a zero nutrient balance (a FALSE or alternative system calculated by QUEFTS, section 2.8). As observed in the previous sections, for some crop rotation the current fertilizer gifts are not high enough and lead to negative nutrient balances. For other crop rotations, the fertilizer gifts are too high, leading to nutrient losses and too high costs.

Nutrient requirements calculated by QUEFTS (Table 3.15) are compared with the current situation. There is variation in nutrient use efficiency in different crop rotations. The nutrient requirements recommended by QUEFTS in conventional methods are lower than nutrients currently applied to the farm, except in the cases where onion or ragis are part of the crop rotation. The nutrient uptakes of these crops are higher than what is currently supplied. The farmers apply nothing or very low amounts of fertilizer for ragi crop because they think that it is a common variety and does not need more fertilizer. The nutrients recommended for maize and sunflower crops are low as crop nutrient requirement for the target yield is almost equal to the long-term soil nutrient supply, so it recommends very low amount of nutrients. Phosphorous is available in medium amount in the soil so the model does recommend low amounts of nutrients. Potassium is present in large amounts in the soil, so the model doesn't recommend these nutrients at all.

Table 3.15 Nutrient requirements for different crop rotation in red and black soil of Chitradurga calculated by QUEFTS (technology E and F).

Chitradurga Red soil	CONVENTIONAL			ORGANIC		
Crop rotation	N	P	K	N	P	K
Maize- Sunflo	5.6	0	0	0	0	0
Ragi-Gnut	2	3.1	0	0	0	0
Ragi-Maize-Sunflo	102.1	22.6	0	120.5	8.9	0
Ragi-Maze-Gnut	82.5	18.3	0	117.8	7.6	0
Ragi-Sunflo-Gnut	58.3	20.5	0	14.2	4.6	0
Maize- Sunflo- Gnut	63.9	6.5	0	22.3	6.7	0
Sunflo-Ragi	15.2	5.5	0	0.3	0.6	0
Maize-Ragi	30.8	8.1	0	0	0	0
Onion-Maize-Sunflo	204.1	70	0	246.2	57.2	1.8
Onion-Ragi- Gnut	208.7	77.6	0	150.6	53.8	0
Onion-Maize-Gnut	215.8	79	0	236	55.3	0
Gnut-Ragi	191.7	67.3	0	36.4	0	0
Gnut-Maize	2.3	3.4	0	100.7	0	0
Gnut-Sunflo	0	0	0	33.7	0	0
Onion-Sunflo	154	54.7	0	113.8	41.3	0
Onion-Ragi	152.1	54.6	0	116.5	42.1	0
Maize-Gnut	0	0	0	0	0	0
Chitradurga Black soil	CONVENTIONAL			ORGANIC		
Crop rotation	N	P	K	N	P	K
Maize- Sunflo	0	26	0	0	18.5	0
Ragi-Gnut	0	29.7	0	0	10.6	0
Ragi-Maize-Sunflo	46.8	62.7	0	80.5	50.2	0
Ragi-Maze-Gnut	39.7	44.9	0	78.3	42.3	0
Ragi-Sunflo-Gnut	27.7	53.7	0	0	37.2	0
Maize- Sunflo- Gnut	28.7	34.9	0	7.8	28.5	0
Sunflo-Ragi	0	45.6	0	0	36.5	0
Maize-Ragi	6.4	38.5	0	0	15.1	0
Onion-Maize-Sunflo	142.4	104.6	0	162.5	97.1	0
Onion-Ragi- Gnut	138.3	110.4	0	106.3	81.1	0
Onion-Maize-Gnut	142.4	125.4	0	152.9	89.5	0
Gnut-Ragi	138.3	86.7	0	14.1	23	0
Gnut-Maize	0	29.4	0	45.1	31.7	0
Gnut-Sunflo	0	7.5	0	12	26.3	0
Onion-Sunflo	105.3	86.6	0	74.1	74.4	0
Onion-Ragi	102.8	99.4	0	76.2	71	0
Maize-Gnut	0	7.9	0	0	1.4	0

For organic farming having three crops in a rotation, higher nutrient applications are recommended than applied in the current situation. Especially in ragi where there is no application of fertilizer by the farmer. The nutrient applied for onion crops are almost same as nutrient recommended by QUEFTS. Overall, the results recommend more nutrient application for organic land use types.

These results also demonstrate that nutrient use efficiency of crops in organic is more than conventional farming systems because the yields in organic are almost the same or more than in conventional, and applied nutrients are generally lower. Target yields, here based on observations, determine the nutrient requirements. Table 3.15 also shows that the fertilizers applied for crop rotations having three crops are not sufficient to meet the nutrient demand of the crops. As most farmers in Chitradurga prefer to grow only two crops in the year, in general the fertilizer applied per crop and soil nutrient supply are sufficient to meet their demand. In the future, if farmers need to increase the production, they have to ensure nutrients are available for the crops in organic farming systems.

The results for Mysore are very different from Chitradurga. There is significant difference in the application of nutrients between organic and conventional methods of farming (Table 2.6). A larger amount of nutrients are applied for crops like sugarcane, rice, cotton and cowpea in conventional methods compared to organic methods. The amount of fertilizers applied in the organic farms in Mysore growing rice, sugarcane and cotton were almost in their upper limit of available fertilizers.

When we compared fertilizer gifts with nutrient requirements recommended by the QUEFTS then large differences are observed (see Table 2.6 and Table 3.16). For the leguminous crop lentil and cowpea, this is because the model calculates the atmospheric nitrogen fixation, which is enough or more than nutrient uptake by the crops. Timing of fixation and availability of those nutrients in next cropping season is not properly calculated by the model however, which may influence the results.

In contrast to Chitradurga, nutrient use efficiency is lower in Mysore in organic farming. The reason is that actual nutrient uptake in organic land use types is low compared to the nutrient supplied. This may be due to pest and disease incidence, lowering the yields. We also saw that the pesticide application is almost at permissible level in this area (section 3.2.2). Except sugarcane, no high nutrient applications for organic land use types are recommended. Nutrient recommendations for the conventional systems are higher than for organic, mainly because yields are higher.

Table 3.16 Nutrients requirements for different crop rotation in Mysore calculated by QUEFTS (Technology E and F).

Mysore red soil	CONVENTIONAL			ORGANIC		
Crop rotation	N	P	K	N	P	K
Sugarcane	247.5	40.7	0	174	15.9	0
Rice-Cowpea-Sesame	85.9	0	0	0	0	0
Rice-Cowpea-Rice	160.7	0	0	0	0	0
Rice-Cowpea	3.5	0	0	0	0	0
Rice-Ragi-Rice	173.9	0	0	19.3	0	0
Cotton-Cowpea-Sesame	20.9	0	0	0	0	0
Cotton-Cowpea-Rice	59.9	0	0	0	0	0
Cotton-Cowpea	0	0	0	0	0	0
Cotton-Ragi-Rice	149.6	0	0	18.5	0	0
Tur-Lentil-Ragi-Rice	26.5	0	0	13.2	0	0
Cowpea-Ragi-Rice	69.1	0	0	8.7	0	0
Cowpea-Ragi	0	0	0	0	0	0
Ragi-Cowpea-Rice	146.5	29.4	0	56.6	0	0
Ragi-Cowpea	0	3.6	0	0.7	0	0

Even in conventional land use types the nutrient recommended is almost or more than half of the nutrient application. Phosphorous and Potassium recommendation is almost nil in both conventional and organic systems except in the sugarcane and rice.

4. Discussion

In this part the different results are discussed in the following points, which will cover all ecological and economical indicators and also include optimal fertilizer recommendations calculated by QUEFTS. The sections refer to the research questions: 4.1 Sustainability of organic versus conventional farming, 4.2 Projecting changes in organic and conventional farming towards 2015, 4.3 Sustainability of farming systems in Chitradurga versus Mysore, 4.4 Impacts of crop failure on debts. 4.5 Using TechnoGIN to assess sustainability of farming and 4.6 Recommendations to policy makers.

4.1 Sustainability of organic versus conventional farming

In terms of economic sustainability, organic agriculture is suitable if farmer benefits from it (Kolanu and Kumar, 1998). It needs a different system approach than conventional, as managerial ability significantly affects labour requirements, fertilizer costs and economic returns (Brunfield et al., 2000). The interest in organic agriculture in India is growing because it requires less financial inputs and places more reliance on the natural and human resources available (Ramesh et al., 2005). Unlike developed countries, India doesn't have high costs of labour. In the case of the villages in Karnataka assessed in this thesis, labour requirements for organic remain the same as for conventional system. Still, net profits in cash crops will be higher in conventional because organic systems have poor yields and have no premiums due to poor infrastructure such as no certification and lack of market information. The most important factor is the cost of fertilizers, which determines the difference in economic sustainability between organic and conventional farming. Crops in Chitradurga have low inputs, and therefore fertilizer costs of organic were lower than conventional farming. The costs in organic were lower because farmers use their own farm yard manure and vermicompost which is sufficient for adequate nutrient supply to the crops. Hence, they don't need to purchase fertilizers from outside. In Mysore, crops require more organic fertilizers to get adequate nutrient supply for the crops, so they have to purchase more from outside and consequently fertilizer costs are higher for organic farming compared to conventional farming in that region

In the end, higher net profit in organic farming results from crop rotations which have low inputs in terms of labour, fertilizers and in the meantime obtain yields similar to crop rotations in conventional farming. Crops such as ragi, groundnut, cowpea and tur lentil are generally not commercial crops or cash crops which imply that the harvest will not contribute to the profit and hence reduces the income of the farmers. Results clearly indicate that if farmers want to increase their income with organic farming they need combinations of higher yields and price premiums or direct subsidy by the government or helpful market policies.

In terms of ecological sustainability, organic is more sustainable than conventional because the nitrogen losses are lower, the biocide index is zero as they do not apply pesticides and if the yields are lower, it is less water intensive. There are nitrogen losses and surpluses both in conventional and organic farming but these depend on the crops present in the crop rotation. The intensive cultivation of crops like rice, cotton and onion can increase the problem of soil salinity in the future and other environmental impacts like loss of biodiversity due to of excessive application of fertilizers. Soil salinity problems are encountered in almost all districts in Karnataka (Swarajyalaksmi et al., 2003). Searching for other literature, no empirical scientific evidence was found in these districts indicating higher organic fertilizer application will have less nitrogen losses than conventional.

A study from Norway shows organic systems have higher leaching than conventional (Korsaeth, 2008). The loss of nutrients in organic manures is less due to slow release (Bhattacharya, Chakraborty, 2005). But when considering the efficiency of fertilizers, conventional fertilizers are more efficient than organic fertilizers. There is no scientific evidence of how much nutrients get lost from organic manure or vermicompost when kept in the open pit. Our results suggest that there is nutrient mining in some organic crop rotations which indicates there is lack of nutrient supply.

The magnitude of nitrogen leaching calculated by the model assuming a long term nutrient supply of 114 kg N /ha is high compared to other studies in different countries (Kirchman and Bergstrom, 2001; Syvasalo et al., 2006; Torstensson et al., 2006; Korsaeth, 2008). Therefore, as explained in 2.7.1, a sensitivity analysis was performed, adapting the available long term nutrient supply. So to test the influence of soil N supply on nutrient balances, calculations were also performed with soil N supply of 50.5 kg/ha/yr instead of 114 kg/ha/yr (see LMU sheet). Table 4.1 and 4.3 indicate results of nitrogen surplus in kg/ha and Table 4.2 and 4.4 are the results of nitrogen loss in kg/ha in Chitradurga and Mysore if the long term supply of nitrogen is 50.5 kg/ha as calculated based on available data.

Table 4.1 demonstrates that with a soil N supply of 50 kg N/ha/yr, there is depletion of nutrients in organic farming of Chitradurga, while conventional shows almost 0 nitrogen surpluses. These seem more realistic values as compared to the previous mentioned in the results (see result 3.2.4) as applied nutrients in organic systems are much lower than what conventional farmers generally apply. Nitrogen surplus and nitrogen loss in Mysore and Chitradurga are low compared to the previous results. The above tables clearly indicate that expert knowledge of available nitrogen can be disputed. A thorough soil analysis of both of villages is needed and then experts can recommend fertilizer doses in both in organic and conventional crop rotation at farm level.

Another indicator of ecological sustainability is pesticide use. The use of pesticide is low as compared with other countries like Taiwan, where the average farmer uses 17 kg per hectare, Japan uses 12 kg per hectare and Korean farmer use 6.6 kg per hectare (Chandrasekhar, 2005). Most of the conventional crop rotation in Chitradurga have a biocide usage with active ingredient less than 0.5 kg/ha, which is less than the average Indian farmer biocide application of 0.5 kg/ha (Chandrasekhar, 2005). In Mysore however, there are crop rotations having crops like sugarcane, rice, cotton and cowpea which need more pesticide application. But it is not in alarming condition so there is not big problem of environmental hazards due to pesticides application.

Lastly, there are some crops which are highly water intensive and need more irrigation water, but there is no scientific evidence about differences in water use efficiency between organic and conventional farming.

Overall organic agriculture can deliver agronomic and environmental benefits both through structural changes and tactical management of farming system.

Table 4.1 Nitrogen surplus with N soil supply of 50.5 kg N/ha, Chitradurga

N surplus (kg/ha)	Conventional	Organic
Maize- Sunflo	0	-16.8
Ragi-Gnut	0	-4.4
Ragi-Maize-Sunflo	-32.4	-84.3
Ragi-Maze-Gnut	-6.4	-76
Sunflo-Maize	0	-80
Sunflo-Maize-Gnut	0	-96.7
Sunflo-Ragi-Gnut	-7.2	-47.4
Sunflo-Ragi	0	-29
Maize-Ragi	-0.6	-22
Gnut-Ragii	0	-33
Gnut-Maize	0	-86
Onion-Maize-Sunflow	-29.5	-92
Onion-Ragi-groundnut	-4.5	-30
Onion-Ragi-Sunflow	-16.7	-42
Onion-Maize-Gnut	-4.5	-86
Onion-Sunflo	0	-21
Onion-Ragi	0	-20
Maize-Gnut	0	-3

Table 4.2. Nitrogen loss with N soil supply of 50.5 kg N/ha, Chitradurga

N loss (kg/ha)	Conventional	Organic
Maize- Sunflo	78	17.2
Ragi-Gnut	94.2	27.3
Ragi-Maize-Sunflo	66.4	18.7
Ragi-Maze-Gnut	88.6	25.1
Sunflo-Maize	83.6	19.7
Sunflo-Maize-Gnut	98	23.5
Sunflo-Ragi-Gnut	106.6	16.9
Sunflo-Ragi	87.5	11.3
Maize-Ragi	67.7	11.3
Gnut-Ragii	96.7	14.3
Gnut-Maize	92.8	24
Onion-Maize-Sunflow	150.3	46
Onion-Ragi-groundnut	177.4	38.1
Onion-Ragi-Sunflow	141.4	29.6
Onion-Maize-Gnut	173.6	51.1
Onion-Sunflo	174.4	52.5
Onion-Ragi	161.1	40.9
Maize-Gnut	103.9	24

Table 4.3 Nitrogen surplus with soil supply of 50.5 kg N/ha, Mysore

N surplus (kg/ha)	Conventional	Organic
Sugarcane	-70.5	-73
coconut	2.1	10.6
Rice-Cowpea-Sesame	36.5	13.8
Rice-Cowpea-Rice	26.7	29.6
Rice-Cowpea	26.7	29.6
Rice-Ragi-Rice	0	-11.3
Cotton-Cowpea-Sesame	11.8	31.7
Cotton-Cowpea-Rice	-9.4	21
Cotton-Cowpea	6.2	39.2
Cotton-Ragi-Rice	-23.3	-4.1
Tur-Lentil-Cowpea-Sesame	35.7	24
Tur-Lentil-Cowpea-Rice	56	14.8
Tur-Lentil-Cowpea	25.2	23
Tur-Lentil-Ragi-Rice	6	-7.6
Cowpea-Ragi-Rice	16	7.4
Cowpea-Ragi	32	24
Ragi-Cowpea-Rice	-36	-11
Ragi-Cowpea	-9	8

Table 4.4 Nitrogen loss with soil supply of 50.5 kg N/ha, Mysore

N loss (kg/ha)	Conventional	Organic
Sugarcane	77.5	52.2
coconut	37.2	29.6
Rice-Cowpea-Sesame	196.8	172.2
Rice-Cowpea-Rice	229.7	85
Rice-Cowpea	154.3	65.6
Rice-Ragi-Rice	228.9	69.6
Cotton-Cowpea-Sesame	138.7	96.6
Cotton-Cowpea-Rice	174.5	83.4
Cotton-Cowpea	91.9	51.4
Cotton-Ragi-Rice	169.5	71.1
Tur-Lentil-Cowpea-Sesame	130.6	74.9
Tur-Lentil-Cowpea-Rice	181	83.6
Tur-Lentil-Cowpea	88.7	62.2
Tur-Lentil-Ragi-Rice	155.9	68.7
Cowpea-Ragi-Rice	186.1	73.7
Cowpea-Ragi	103.2	42.3
Ragi-Cowpea-Rice	184.3	77.9
Ragi-Cowpea	91.2	43.7

4.2 Projecting changes in organic and conventional farming towards 2015

Changes will take place in the future, as cost of inputs and outputs will increase with increasing oil prices and changing markets (Chandrashekhar, 2009). The profit in organic farming is expected to improve, because of the higher premium price for organic products. Furthermore, if a farmer adopts good management practices such as optimal nutrient management, crop rotations with legumes crops and pest management practices, the yields in both conventional and organic can increase. In our calculations, no yield increases were considered as there was no increasing trend in the last years. As for the current situation, cash crops like onion and rice still have more yield which results in more profit in conventional than organic farming. These will be more sustainable in economic terms. Nevertheless, there is a problem of N losses and N surplus in these systems, so in the future more leaching may occur if cultivation becomes more intensive. For organic farming, there is a problem of nutrient depletion which can be hazardous for fertility of the soil in future. This may also be the reason of the low yields that are observed for organic compared to conventional for some crops like onion and sugarcane.

4.3 Sustainability of farming systems in Chitradurga versus Mysore

According to the Central intelligence agency, the purchasing power parity of India in 2008 was $2,800 per person; when converting into Indian rupees this is INR120,400. The main difference between Chitradurga and Mysore is that they have different crops resulting in different land use types. Different crop rotations have different incomes, so it is hard to compare the income between Chitradurga and Mysore. Crops which are profitable in conventional and having more risk of debts are grown in Mysore and crops which are profitable in organic and having low risk of debts are grown in Chitradurga

A conventional farmer in Mysore with 1 ha of conventional farm producing crops like rice and cotton obtains an income which is close to annual purchasing power parity. In Chitradurga however few cash crops are grown but profit is mainly higher in organic farming. The income in conventional farming is four times lower than purchasing power parity. The income per ha is similar to what was presented for small and marginal farms in Table 1.1

Ecologically there is nutrient surplus in Mysore and nutrient mining in Chitradurga
In general, N loss in Chitradurga is low as compared to Mysore in both conventional and organic farming.

Crops grown in Chitradurga can be grown in Mysore, but the crops in Mysore cannot be grown in Chitradurga as these are highly water intensive crops and can be affected by drought and pest incidence. Cultivating these would likely result in more debts. Introduction of leguminous crops in the crop rotation is a good option as it can decrease the problems of nutrient mining.

4.4 Impacts of crop failure on debts

Agrarian distress occurs when farmers experience total failure of crops as a result of sudden drought or sever pest incidence in the crop production in that whole year. Crop failure often takes place due to uncertainty in rainfall and pest incidence due to geographic conditions (Chandrashekhar, 2006). The results clearly indicate that when crop failure occurs, farmers are more in debt with conventional farming in Mysore and Chitradurga. Introduction of organic farming can reduce distress as it is a low cost farming system. The difference in debts between conventional and organic is due to high chemical fertilizer and pesticide costs. In the future, debts in conventional will increase due to increasing labour, pesticides and chemical fertilizer costs. Farmers cultivating high input crops have more debts than farmers growing local food grain crops. In organic farming, if farmers do not have their own vermicompost, it is difficult to just depend on farm yard manure because it will not supply adequate amount of nutrients. So, farmers may have to buy vermicompost which can be costly and result in more debts.

4.5 Using TechnoGIN to assess sustainability of farming

TechnoGIN is a tool for researchers to analyze economical and environmentally feasible crop rotations in the region of Southeast Asia. TechnoGIN can also project changes in management practices which may be stimulated by policy reforms and farmer willingness to increase the yield. The indicators such as profit, nitrogen losses and nitrogen surplus help researchers to recommend farm management practices to farmers and policy to policy makers. It also helps farmers by recommending optimal application of the fertilizers which are economically sustainable and also have less environmental impacts such as nil nitrogen surplus and low nitrogen loss. Flows of nutrients can be visually presented for every crop rotation in the field. Flows of nutrients can indicate where there is loss of nutrients and which management practices can be used to decrease the loss. There is an environmental indicator of pesticide application which is the BRI index. This BRI index is useful to know at which level farmers are applying pesticides and if this is harmful or hazardous to nature or not.

One feature which can be interesting, but also limit reliability of results, is that to calculate fertilizer costs, TechnoGIN optimizes the use of fertilizer types which are most cost efficient in supplying nutrients. This optimal selection of fertilizer types usually does not represent the actual situation however. The results of fertilizer costs shown by TechnoGIN were different than fertilizers used by the farmers in the current situation. Therefore some own calculations were added to the TechnoGIN calculations (Table 3.1-3.4).

As mentioned in 4.1 about sustainability between organic and conventional farming, estimation of soil nitrogen availability is also difficult, and it influences the nutrients recommended by TechnoGIN and the nutrient losses. Farmers do not know the soil health conditions and apply fertilizers randomly based on availability at near by markets. Results and recommendations from TechnoGIN depend on the input data, so more soil tests would improve the outputs.

Another limitation of TechnoGIN encountered is that it has some problems in the fertilizer sheet when values of nutrient concentrations in fertilizer types are below one. When the values of fertilizers like vermicompost and farm yard manure are below one then the solver in QUEFTS model cannot optimize the result properly. This was solved as explained in section 2.11.2. Finally, in TechnoGIN there is no coefficient where we can use intercropping in the crop rotation.

Concluding, TechnoGIN is a good tool to assess the sustainability of crop rotations using different methods and comparing different regions, but results have to be evaluated and complemented with own calculations.

4.6 Recommendations to Policy makers

The recommendations based on my research results are:

1) The policy of giving subsidies for making vermicompost should not change for new farmers. Direct subsidies for farmers to buy cattle and grant during the conversion period from conventional to organic may be good support to the farmers. This way, the farmers are able to produce the required amount of vermicompost at less expenses.

2) Subsidies on proper infrastructure such as storage houses, and logistics can decrease transaction costs of both conventional and organic products which can increase the income of farmers.

3) It is necessary to get a premium price to organic products for higher profit.

4) In different climatic regions, certain soil types may not supply enough nutrients for certain organic crop production, so research on cropping patterns should be done. For example, promote the cultivation of local food grain crops or local varieties of crops which require low inputs as compare to other higher inputs crop production. Not all crop rotations or land use types can be profitable through organic agriculture, but it is less risky in terms of debts than conventional agriculture.

These recommendation are based on my experiences of my field visits in the two different villages of different districts

1) Proper education of organic farming and market information to the farmers should be given by the Department of organic agriculture of the agricultural university or government bodies like Krushi Vigyan Kendra. Research on improving yields of organic crop production and front line demonstration of research should be carried out in the village itself. Hence farmers will be stimulated to go for organic crop production.

2) Strict implementation of organic practices should be done by providing free organic certification and accreditation of government to improve their standards and having regular inspection on quality of product to get premium prices in the market. This implies that applying synthetic chemicals in the organic crop production has to be terminated.

5. Conclusion

The study of organic and conventional farming system in two villages of two districts Chitradurga and Mysore in Karnataka for comparing economic and ecological sustainability concluded that organic and conventional farming have their own benefits and drawbacks in different districts. In the following are benefits and drawbacks of organic farming in the Chitradurga and Mysore districts.

Chitradurga district:

Benefits of Organic farming:

- Organic is more profitable for crop rotations including ragi, maize sunflower and groundnut, but it is not profitable for crop rotations including onion in the kharif season as in the current situation 2008.
- In the future 2015, the 30% premium price expected for organic products increases the profit further; even for crop rotations with onion, the profits come closer or is higher than conventional.
- Lower risk of debts in organic farming compared to conventional due to lower costs involved; fertilizer costs are lower for all organic crop rotations and there is no use of biocides.
- Lower nitrogen losses in organic compared to conventional farming system.
- Yields of crops like maize in rabi season, sunflower and groundnut in kharif and again groundnut in summer season are comparable or higher than in conventional farming system.
- There is a nutrient surplus for crop rotations having two crops (with soil supply of 114 kg N/ha), except for groundnut and maize. This suggests that lower yields are not due to insufficient NPK supply, but due to pest and disease incidence or other factors like lack of water.

Drawbacks:

- Depletion of nutrients in organic farming systems with three seasons. In other crop rotations, the N balance in soils having 114 kg N/ha is fine but if soil supply would be 50 kg N/ha then negative balances are observed.
- Lower yields for most crops, except maize in rabi season, sunflower in kharif season and groundnut in kharif and summer season.
- Onion is cash crop in this area, but the profit is higher in conventional farming than organic farming.

Mysore district:

Benefits of Organic farming:

- Low nitrogen losses in organic compared to conventional farming systems.
- N balance are positive, often more than for conventional (except tur-lentil). This implies that lower yields are not due to insufficient NPK supply but there are chances of pest and disease incidence
- Low risk of debts in organic farming compared to conventional but the difference in debts is very small. Fertilizer costs are lower in crop rotations with only two seasons and for coconut. Costs are also lower because there is no biocide use in organic farming. Only for sugarcane and cowpea-ragi-rice,

debts are not lower when crop failure occurs, but in 2015 this is projected to be the case.

- The Biocide Residue Index reached up to permissible levels for pesticides in conventional but there is no pesticide application in organic farming systems.
- Although profits are currently lower than conventional, with a 30% premium as assumed for 2015, profits are higher for sugarcane and the LUTs tur-lentil-ragi-rice, cowpea-rice and ragi-cowpea.

Drawbacks:

- Lower crop yields in organic, which seems mainly due to pest and disease incidence in the fields. As the nitrogen fixing crops like cowpea do not reach potential yields, this implies that this is not due to insufficient nutrient supply. Only for tur-lentil and sesame yields are not lower, but at the same level.
- Higher profits in conventional compared to organic in the current situation and in the future 2015 in all crop rotations, specifically when including crops as cotton and rice.
- Nutrient depletion is observed in organic sugarcane, but for most other crops a higher N surplus is observed for organic.

Thus, Karnataka state policy of organic farming can decrease agrarian distress by reducing the burden of debts due to low input costs farming system. While for high input crops it can lead to low yield and low profit; however it will all depends on the farmers objectives and local conditions. This thesis compared two villages in two different districts. Results cannot be directly generalized for the whole districts or the whole state Karnataka, but the comparison shows that the sustainability of organic farming compared to conventional farms can vary due to differences in the crops rotations, soil conditions, management and prices. This variability should be considered when stimulating organic farming.

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