Status of organic agriculture in Sri Lanka

with special emphasis on tea production systems

(*Camellia sinensis* (L.) O. Kuntze)

Dissertation
zur Erlangung des Grades
„Doktor der Agrarwissenschaften“
am Fachbereich Pflanzenbau
der Justus-Liebig-Universität Gießen

PhD Thesis
Faculty of Plant Production,
Justus-Liebig-University of Giessen

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OCTOBER 2004

Acknowledgement

The author gratefully acknowledges the financial assistance received from the German Academic Exchange Service (Deutscher Akademischer Austauschdienst, DAAD) for the field work in Sri Lanka over a peroid of two years and the „Hochschul- und Wissenschaftsprogramm (HWP)“ for supporting the compilation of the thesis afterwards in Germany.

My sincere thanks goes to my teacher Prof. Dr. J. Sauerborn whose continuous supervision and companionship accompanied me throughout this work and period of live. Further I want to thank Prof. Dr. Wegener and Prof. Dr. Leithold for their support regarding parts of the thesis and Dr. Hollenhorst for his advice carrying out the statistical analysis. My appreciation goes to Dr. Nanadasena and Dr. Mohotti for their generous provision of laboratory facilities in Sri Lanka. My special thanks goes to Mr. Ekanayeke whose thoughts have given me a good insight view in tea cultivation.

I want to mention that parts of the study were carried out in co-operation with the Non Governmental Organisation Gami Seva Sevana, Galaha, Bio Foods (Pvt) Ltd., Bowalawatta, the Tea Research Institute (TRI) of Sri Lanka, Talawakele; The Tea Small Holders Development Authority (TSHDA), Regional Extension Centre, Sooriyagoda; The Post Graduate Institute of Agriculture (PGIA), Department of Soil Science, University of Peradeniya, Peradeniya and The Natural Resources Management Services (NRMS), Mahaweli Authority of Sri Lanka, Polgolla. Representing the many people behind these institutions I like to name Mr. Ranjith de Silva, Dr. Sarath Ranaweera, Dr. Modder, Mr. Ashoka Someratne and Mr. Roger White.

Apart from the research I want to express my deep appreciation for the hospitality and genuine friendliness my family experienced during our stay in Sri Lanka.

Last but not least I want to thank my parents, in laws, husband and children for supporting me throughout this challenging period of life.

CONTENTS

1 Introduction

Sri Lanka's agriculture is characterized by two sectors of opposite structure existing next to each other: plantation management versus smallholder production. Both sectors can be distinguished by their typical production system. The plantation sector was implemented during colonial times and is characterized by production units larger than 20 hectares and socially structured in a hierarchic order. Crops are cultivated in monoculture mainly for the export market. Production is labour intensive with high investment rates for artificial fertilizer, pesticides, High Yielding Varieties (HYVs), equipment, infrastructure and factories where processing is taking place.

The smallholder sector is very heterogeneous partly representing the traditional way of agricultural production, characterized by production units smaller than 20 hectares maintained with family labour. For 1.47 million smallholders in 2002 production on an average land size of 0.05 ha was mainly self-sufficient and for the local market due to small quantities produced, a lack of transport facilities and poor infrastructure. Investments were low and artificial fertilizers and pesticides hardly used. Mixed cropping was mainly done in an unsystematic way. Where as 1.78 million smallholders with an average land size of 0.8 ha concentrated on cash crop cultivation of rice, tea, rubber and coconuts including the necessary inputs. If tea and rubber were grown the harvest was sold to neighbouring plantations for processing. Several forms in transition can be found. The total number of smallholders increased from 1.8 million in 1982 to 3.2 million in 2002 reducing average production units through fragmentation from 0.8 ha to 0.46 ha (Department of Census & Statistics, 2002 a).

For many smallholders income generation from agricultural production did not meet household expenditures. Income was secured through off farm employment, very often resulting in land migration. Income distribution left 22 % of the rural population below the poverty line (Anonym, 2000; Munzinger Archiv, 1998). Besides through colonisation and population growth land was taken for intensive agricultural and industrial use at the cost of the natural forest. This intensification has caused a reduction in biodiversity, increase in soil erosion and a loss of soil fertility. In an economy where agriculture accounts for 18 % (1997) of the Gross Domestic Product (GDP), being the largest employer with 38 % of the labour force in 1998 and contributing 23 % of foreign exchange revenues, land degradation is a cause for particular concern (CBS, 1999). Knowing that in spite of the endeavour, Sri Lanka is not self sufficient in its staple food crop production, the smallholder production is of crucial importance for the countries self subsistence, rural economy and biodiversity conservation.

This study focused on the tea smallholder production system in the mid country of Sri Lanka, which is also facing these problems. In Kandy District approximately 14,198 smallholders cultivated an extent of 9,732 ha tea in 1994. About 77 % of these tea smallholdings were 0.4 ha in size with an average yield level of 4,585 kg green leaf per hectare (TSHDA, 1997). Next to

fragmentation and uncertain ownership patterns, lack of infrastructure and market access were reasons for low productivity.
Since age-old systems can become unsustainable under changing conditions, alternatives and different objectives of production are required for the survival of the population (Hayami and Ruttan, 1995; van der Ploeg and Long, 1994). In response to the changing circumstances of farming in Sri Lanka, a number of non-government organisations (NGOs), private companies and international projects have been promoting the dissemination of organic farming. Since the mid 1980s several projects were established growing a variety of organic crops for local and international markets.

The main purpose of this study was to describe and analyse a group of organic tea smallholders in Kandy District to evaluate their cultivation system, which might be successful in terms of economical return and ecological sustainability. Based on the understanding of the organic cultivation system and measures that have to be taken in order to increase the productivity, a site-specific model of a sustainable organic tea smallholder garden was designed.

The study constitutes of four major parts:

- The first part provides background information about Sri Lanka and its social, economic and ecological situation in relation to agriculture and tea cultivation. Further a brief introduction about the principles of tea cultivation for better understanding of the research question was included. An introduction into organic agriculture including statistics of own survey data regarding the recent situation of certified organic production in Sri Lanka closes this chapter.
- Part II aims at a presentation of the survey results regarding the organic tea production systems on smallholder and estate level.
- Part III focuses on the analytical work of field trials carried out regarding the effect of bioslurry, goat compost and bokashi, used as organic amendments on the growth, establishment and yield of tea plants.
- In Part IV the research findings enter into tea smallholder model farm.

Method

During the research period in Sri Lanka (November 1997 – October 1999), data were collected from two organic tea smallholder (TSH) groups organised under Gami Seva Sevana (GSS) and Bio Food (Pvt.) Ltd. compromising of 522 TSHs. Both groups were situated in the mid country region, Central Province, Kandy District, Grama Niladari Division Udapalatha. Visits of five organic tea estates situated in the up country region, Badulla District made it possible to include additional information about organic plantation management.
A trial field was established to study the effect of organic amendments on the establishment, growth and yield of tea by measuring different growth parameters and yield comparison.

Laboratory investigations reflected the soil microbial activity influenced by different organic amendments.

Parts of the study were carried out in co-operation with the Non Governmental Organisation Gami Seva Sevana, Galaha, Bio Foods (Pvt) Ltd., Bowalawatta, the Tea Research Institute (TRI) of Sri Lanka, Talawakele; The Tea Small Holders Development Authority (TSHDA), Regional Extension Centre, Sooriyagoda; The Post Graduate Institute of Agriculture (PGIA), Department of Soil Science, University of Peradeniya, Peradeniya and The Natural Resources Management Services (NRMS), Mahaweli Authority of Sri Lanka, Polgolla.

Part I Background

2 Sri Lanka

Occupied by the Portuguese in the 16th century and the Dutch in the 17th century, the island was ceded to the British in 1802. As Ceylon it became independent in 1948 and changed its name to Sri Lanka in 1972. Tensions between the Singhalese majority and Tamil separatists erupted in violence in the mid-1980s followed by an ethnic war that has weakened the country's economic and social development for nearly two decades. Peace talks are ongoing. The war situation was one of the main reasons for the lack of updated national statistics.

2.1 Location, population, climate, geography

Sri Lanka is an island covering an area of 65,000 km^2. It is situated in the Indian Ocean close to the southern tip of the Indian Peninsula between 5° 55' and 9° 50' N latitude and between 79° 42' and 81° 52' E longitude (Fig. 1). In 2002 the total population of Sri Lanka as estimated by the UN was 19 million people with a growth rate of 1.7 and population density of 303 persons km^{-2} (Department of Census and Statistics, 2003) with a share of 74 % Singhalese, 12 % Ceylon- or Jaffna-Tamils, 5 % Indian- or Kandy-Tamils, 7 % Moors, Burghers (Portuguese and Dutch ancestors) and Vedas (indigenous people) (Munzinger Archiv, 1998). Most of its inhabitants emigrated from India about 500 BC.

The climate is characterized by the predominance of the monsoons during 7.5 months of the year with rainfall ranging from 1075-5450 mm per year and an average temperature of 24.4 °C (Fuchs, 1989). Geographical factors divide the island into two major climatic regions: A 'wet zone' in the south-western quarter and a 'dry zone' in the north-west/north and south-east (Fig. 2). Within these zones 24 different agro-ecological regions can be described.

Fig. 1 Sri Lanka – geographical location (Munzinger Archiv, 1998)

One of the most important factors influencing agricultural activities is precipitation. This is not evenly distributed throughout the year and in some areas less reliable and less effective than in others. The mean annual precipitation in the wet zone amounts to 2,395 mm with the highest total of 5,450 mm. Therefore the wet zone is characterized by an almost complete exploitation with 80 % of the total land extent being under intensive cultivation. The predominant crops are tea (*Camellia sinensis*), rubber (*Hevea brasiliensis*) and coconut (*Cocos nucifera*) as the major commercial plants occupying 29 % of the total land cultivated. Further cinnamon (*Cinnamomum verum*), cocoa (*Theobroma cacao*), coffee (*Coffea arabica*), cardamom (*Elettaria cardamomum*), cloves (*Syzygium aromaticum*), pepper (*Piper nigrum*), other spices and several types of tropical fruits are grown. The mean annual precipitation in the dry zone amounts to 1,791 mm with the lowest total of 1,075 mm. Only some 30 % of its area is cultivated with rice (*Oryza sativa*) as the predominant crop. Shifting cultivation can still be found and the government is running irrigation programmes to extend and diversify agricultural activities. The annual average of relative humidity over Sri Lanka is 80-85 %.

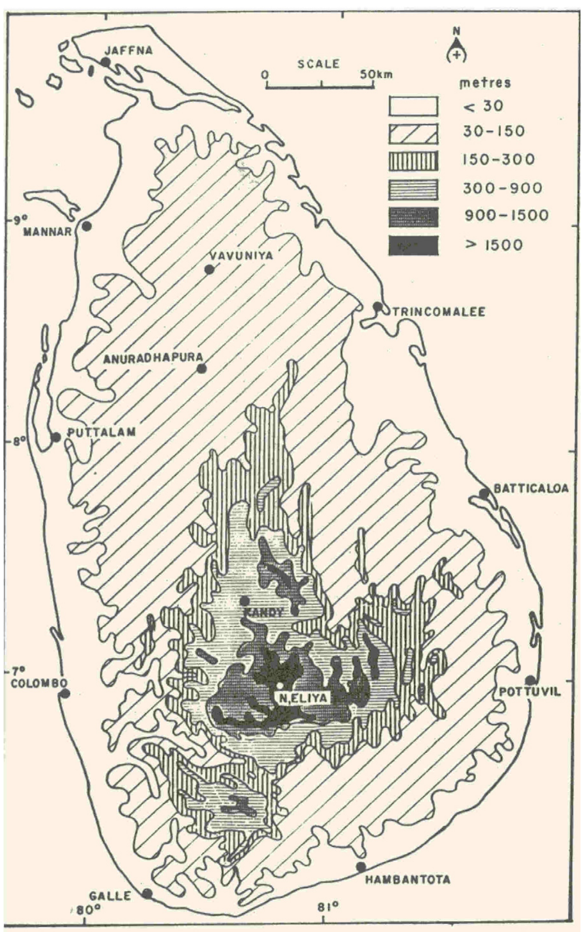

Fig. 2 Relief of Sri Lanka

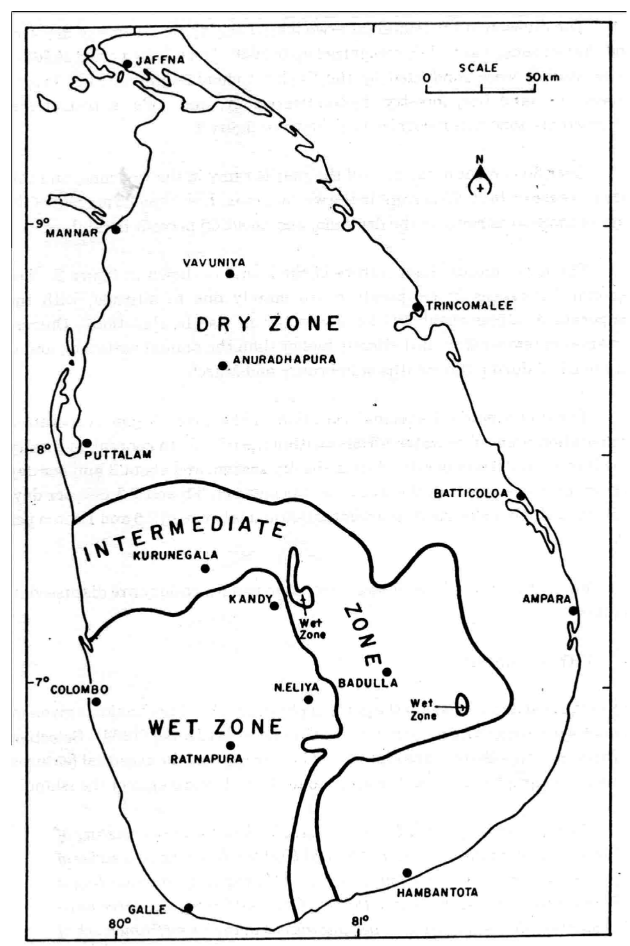

Fig. 3 Climatic zones of Sri Lanka

The relief of Sri Lanka (Fig. 3) comprises a mountainous area in the southern central part (Central Highland) with elevations rising from 900 to 2,100 m, referred to as up country, where mainly tea is grown and in some areas intensive vegetable production takes place. The up country is surrounded by an intermediate zone of upland ridges and valleys with an elevation of 300-900 m, referred to as the mid country. Here rubber is the predominant crop in a belt-like area. The coastal lowland plains, referred to as low country, occupy the rest of the country and are characterized by coconut palms (Fuchs, 1989).

2.2 Economic and social situation

At the time of independence (1948), the plantation sector played a significant role in Sri Lanka's economy. The banking sector, trade and the transport network had all developed initially to support the plantation economy. The export structure became diversified with the emergence of new export items like garments, rubber based products, ceramics, handicrafts, petroleum products, leather products, various spare parts including electronics, canned food and fruit and fish products. With a share of 23.6 % (79.3 % in 1977) the agricultural products lost their leading position of the total export earnings being second after industrial products with a share of 73.4 % (46.4 % textile and garments) in 1996 compared to 14.2 % in 1977. The share of the plantation products on the export of agricultural products was 84 % (CBS, 1998 c). In 2002 the percentage share of the agricultural sector on the gross domestic product (GDP) was 20 %, third after services with 54 % and industry with 26 % (CBS, 2002).

The inflation rate dropped from 15.9 % in 1996 to 7 % in the year 2000. The value of the Rupee decreased from 57.48 SL Rs/US $ in 1997 to 90.45 SL Rs/US $ in 2001. Rises in wages are not sufficient to outweigh the growing costs of living. Even though Sri Lanka left the category of being a Least Developed Country, achieving a per-capita-income of 829 US $ in 1999. Income distribution is leaving 22 % of the population below the poverty line (Anonym, 2000; Munzinger Archiv, 1998).

Sri Lanka is not self sufficient with its food crop production. There was a continuous increase in consumer goods imported between 1994 and 1998. In 1998 Sri Lanka's expenditures for consumer goods reached 80.9 billion Rupees whereas the value of all agricultural exports only reached 70.2 billion Rupees. Main import products are rice, sugar, wheat, potatoes, onions, pulses, milk and dried fish. Reasons for the high import rates are a limited availability of suitable agricultural area (e.g. rice, sugarcane), low production rates, yield per unit (e.g. rice, animals), agricultural policy, a change of nutritional habits (e.g. wheat bread) and internal political problems.

Since July 1996 the government has reduced or waived general import duty and tax on imports of other field crops like onions, potatoes and chilli. Cheap imports, especially from India, have discouraged local farmers who are not competitive and local production went down. The sugar industry is facing declining yields and sugar recovery rates, labour unrest and certain factories operating below capacity. Production in the northern area had to be stopped because of the civil war. Local production was sufficient to meet about 18 % of the domestic demand in 1996. From 1977 onwards, with the change in the economic policies and the liberalisation of imports, the drive towards self-sufficiency in milk production diminished. At present only 20 % of the countries requirements of milk and milk products are locally produced (CBS, 1998 c).

Population density, regional distribution and socio-economic conditions

Sri Lanka is a densely populated country with 284 persons km^{-2} in 1999 compared to 231 persons km^{-2} in 2004 in Germany (Statistisches Bundesamt, 2004). Colombo, Galle, Jaffna, Kalutara, Kandy and Matara are the most densely populated districts with the highest rate of 3,000 persons km^{-2} in Colombo District. Mannar, Moneragala, Mullativu and Vavunia are the most sparsely populated districts with less than 100 persons km^{-2}. In 1981, about 49 % of the population was concentrated on 14 % of the total land area (CBS, 1998 c).

In 1997 in about 56 % of the households electricity was available and 31 % of the households had access to pipe born water. Regarding the availability of household equipment for the year 1997 in 16 % of the households a refrigerator could be found, 3.8 % (6 % in 2001) of the households had a telephone connection, 50 % a television set, 2.9 % a washing machine and 0.4 % a personal computer. In 1997 the literacy rate was 91.8 % (CBS, 1998 b; CBS, 2002).

Employment

With 45.8 % the sector of public administration, defence and other personal services provided the highest employment rate in 2002 followed by the agricultural, forestry and fishing sector with 33.1 % and industry with 21.1 % (CBS, 2002). A significant increase in the average income per income receiver from 1,817 Rupees per month in 1986/87 to 5,760 Rupees per month in 1996/97 is evident. Since 1990 the unemployment rate has come steadily down from 15.9 % to 10.4 % in 1997. In 1998 it went below 10 % to 9.7 %, indicating the lowest rate recorded. But this estimate is not strictly comparable with previous ones, as the latest survey includes unpaid female family workers as being employed. The female unemployment rate declined from 23.4 % in 1990 to 12.7 % in 1998. According to several Censuses for Statistics (CFS) carried out between 1963 and 1987, more than 70 % of the total unemployed belonged to the age group of 15-24 years. Further there has been a continuously higher unemployment rate among persons with higher formal educational qualifications indicating the mismatch between academic training and employment opportunities (Tab. 1). So every year more than 100,000 people (172,000 in 1995) mainly of Indian-Tamil origin leave the country for temporary work in the Middle East (CBS, 1998 a, c).

Tea is a very labour intensive crop, grown over a wide range of conditions in Sri Lanka. In many areas most people are employed directly or indirectly by the estate sector. Each time potentially good tea estate lands are taken for village expansion or settlement, the prospect for long-term improvement of employment opportunities is reduced. In some cases UNDP/FAO (1977) advised to keep land in tea that is only marginally profitable as such estates provide nuclei of paid employment until other, more profitable rural industries can be established. They also provide centres with the processing facilities of tea produced by surrounding smallholders.

Tab. 1 Unemployment rate by level of education (CBS a, 1998)

	Percentage of labour force					
Period	No schooling	Grade 1-4 Year 1-4	Grade 5-9 Year 5-9	O Level Year 10	A Level and above Year 11-13	Total
1998	0.2	2.6	10.2	13.5	16.2	9.7

Malnutrition

Low nutrition among certain segments of the people, particularly pre-school children and pregnant and nursing mothers, has been a continuous problem in Sri Lanka. Protein energy and micro nutrient deficiencies are the most prevalent types of malnutrition. The protracted armed conflict in the northern and eastern provinces since 1983 and the insurgence of 1988-1990 in the south have had a devastating impact on the quality of life of children in the affected areas (CBS, 1998 c).

2.3 Agriculture

2.3.1 Traditional cultivation systems in Sri Lanka

Traditional subsistence agriculture has been practised for nearly 2000 years in Sri Lanka and throughout this period farmers have maintained an ecologically rich and diverse landscape. During the time of colonialism agricultural activities were intensified and structured as plantations to an extend that made it possible and profitable to use artificial inputs promoted through the Green Revolution in order to boost the productivity. Statistics show that fertilizer and pesticides are predominantly used for the export crops and rice (National Fertilizer Secretariat, 1997). The smallholder production for the home and local consumption still takes place mainly without external inputs (in a sustainable manner).

2.3.2 Chena cultivation (slash and burn)

Chena cultivation is probably the oldest form of agricultural land use in Sri Lanka, still practised today in the dry regions of the island. It is characterized by forest clearing and cultivation for one or two seasons, a fallow period and forest regeneration. The Land Use Division of the Irrigation Department estimated chena land to be about 1.2 million ha in 1984. The ecological sustainability of shifting cultivation is only assured if the human population is not growing and the forest reserves are sufficient. Chena size and crop rotation periods underlie variations and influence the ecological viability (Humbel, 1991).

2.3.3 Forest Gardens

Forest gardens are another dominant land use form practised over centuries. The Sri Lanka Survey Department (1988) indicates that 13.5 % of the total area of the island is occupied by forest garden systems. The share of forest gardens of the total land use types in the wet zone is 20.4 % and 13.1 % respectively in the intermediate zone. “Today the gewatta’s (singhalese: homegarden) contribution to conserving the country’s biodiversity, to the protection of soils and the improvement of climatic conditions cannot be ignored “ (Hochegger, 1998).

One example are the “Kandyan Gardens, Kandyan Forest Gardens (KFG)” (Jacob and Alles, 1983) or “Kandyan Homegardens” (Wickramasinghe, 1991) where multi-storey mixed cropping is done in a forest like environment for generations now. The KFGs are most prevalent in the Kandyan region where 45 % of the households own home gardens with diversity as high as 135 species in 1.41 ha (Alison, 1994). The climate (wet mid-altitudes) and socio-economics (high population and rural society) are ideal to maintain such tree gardens with an average size of 0.5-2 ha.

Sellathurai (1997) stated, “The home garden agroforestry system in the study area (Kandy District) is at least 3 generations old. It is multi-storeys (4 strata), has a high plant density (1,883 plants ha^{-1} including 948 woody perennial plants ha^{-1}), closed canopy (>75 % canopy coverage), high species richness (57 species/household), high species diversity index (3.93 Shannon Wiener index), random arrangements of the plants and a dynamic structure resembling the natural forest in both structure and function”. The productivity of the land increased with decreased land size. “From the conservation point of view, home gardens are *in situ* conservation sites for plant and animal species with a total of 237 useful plant species. In addition it continuously provides socio-economic and cultural benefits (e.g. food, fuelwood, timber, medicine, building poles and cash income) for the people. From the study around 80 % of the household fuelwood need is covered by home gardens and this indirectly saves the natural forest. About 0.5 tons of fuelwood per person per year is saved in the study area through use of home gardens. Moreover the system minimises soil erosion in sloping lands and maintains soil fertility. It is a low input productive system and maintains soil fertility by farm generated resources with 80 % of the households using only organic fertilizer for their home lands” (Sellathurai, 1997). In her study “Farming like the forest” Hochegger (1998) documented 640 species in 158 gardens and identified and recorded 28 different categories of uses with the help of local farmers.

With regional differentiation the term “Forest garden” is used by Everett (1991) and “Analog forest garden” by Nuberg et al. (1994) and Senanayake (1997). Analog Forestry is a system of silviculture, which imitates the architectural structure and function of the original vegetation. At the same time the method takes advantage of specific new and exotic species, which have proven to have a high utility value, replacing certain indigenous species that were of low utility. Centuries of forest clearing, to make way for monoculture plantations, rapid, unilateral reforestation programmes (e.g. pine and eucalyptus), and increased use of agrochemicals make it impossible to return to the “original” state of the forest. Analog forestry is a method to restore deforested and degraded lands and to offer people new sources of income, food, and other essential needs. The method has made it possible to restore the microhabitats of existing forests and has seen the return of growing numbers and varieties of birds, mammals, insects, amphibians and reptiles. In 1980 the Neo-Synthesis Research Centre (NSRC) was established in Sri Lanka with the aim to develop methods of land management that reduce erosion, permit soil formation, enhance water quality and biodiversity and provide farmers with a source of income. At present NSRC works with 493 farmers in 6 distinct ecological zones.

“After the decline of natural forests these diverse gardens are the last remnants of biodiversity, the last refuge for the island’s diminishing wild flora and fauna” (Hochegger, 1998). Considered as small enterprises these gardens are building a vast potential and play a major role with regards to organic agriculture and environmental protection. This situation has to be kept in mind when looking at the statistics of certified organic production.

2.3.4 Alternative practices

Erosion is an important and most destructive factor especially in tea cultivation. Several alternative practices like Sloping Agriculture Land Technique (SALT), alley cropping and organic agriculture have been introduced for soil conservation and environmental protection. SALT is a low cost soil conservation system for sloping agricultural lands integrating biological erosion control measures with the existing production system aiming at a sustainable use of the land resources. The Upper Mahaweli Watershed Management Project recommends leguminous species such as *Gliricidia sepium* for SALT hedges. Being an excellent source of energy and protein for milk production they are an important supplement to low protein roughage such as dry grass or rice straw. Making hedges more valuable as on-farm fodder sources can result in a higher adoption of SALT by smallholders with a dairy component. Enhancing the long-term sustainability of smallholder livestock systems should lead to a reduction of over-exploitation of off-farm resources.

2.4 Land use pattern

Out of the total land area of 6.5 million hectares 1.5 million (24 %) are recognised as agricultural land and 1.2 million hectares (19 %) as sparsely used crop land (Department of Census & Statistics, 2002 a). In 2002 the cultivated extent of the major crops was as follows (Tab. 2):

Tab. 2 Cultivated extent of major crops in Sri Lanka (Dep. of Census & Statistics, 2002 a)

Crop	Rice	Tea	Rubber	Coconut
Hectares	852,529	188,971	157,403	443,952

2.5 Animal husbandry

Animal husbandry has a long tradition due to the importance of buffalo and cattle for paddy production. Traditionally livestock was not kept for the purpose of meat production. Due to the vegetarian aspect of Buddhist religion the habit of keeping livestock, which they would have to slaughter is not common among Singhalese farmers. The introduction of goats, pigs and poultry by missionaries and colonialists brought a gradual change of attitude towards animal husbandry and nutritional habits. Commercial animal production is confined mainly to poultry, pigs and some dairy on government farms. An estimated 30 % of the households raise animals. For smallholders, the contribution to the total farm income varies depending on the type of animal between 13 % and 22 % (SLE, 1993).

One major constraint for keeping ruminants is the lack of fodder supply during the drought season. A survey was conducted on the seasonal variation of fodder supply to stable-fed livestock in the mountainous region of Sri Lanka, agro-ecological zone wm2, in order to verify the significance of fodder from hedges with multi-purpose trees grown for erosion control like *Gliricidia sepium* and *Leucaena leucocephala*, also known as the Sloping Agriculture Land Technique (SALT). For the farmers in the research area Gampola the difficult months regarding fodder supply are January, February and March. Not only the lower availability of fodder but also the subsequent time requirement for collecting it from off-farm resources is an important constrain for these farmers. During these months mainly tree leaves, creepers and some grass of poor quality are hand collected within a walking distance of 3 to 5 km from the homestead, which takes about 4 hours per day (Fleddermann, 1992). Many organic tea smallholders have implemented the SALT system and contour planting as a source of shade, additional fodder and organic material.

2.6 Ecology

“Sri Lanka was almost entirely covered by natural forest until the turn of the 19th century. Since that time the closed-canopy natural forest cover has dwindled rapidly from about 80% to less than 24% in 1992. In the light of increasing demands placed upon the forestry sector and its diminishing capacity to meet the various needs of the people, sustainability has become a major problem, which is being felt both at national and local levels. The most serious consequences of forest degradation are the reduction in biodiversity due to destruction of the flora and fauna habitats, irregular water supply, shortened live spans of irrigation channels and reservoirs, soil erosion and associated loss of soil fertility and increased scarcity of wood” (Department of

Census & Statistics, 1998 b). Forest plantations consist of pine trees like *Pinus carbaea* and *Pinus patula* in the up country, *Eucalyptus grandis*, *E. microcorys*, *E. globulus*, *E. roburta* and *Teak grandis* in the mid elevations and dry zone. This inappropriate land use is a result of forest policies not supporting the sustainable forestry development, bringing about the same consequences as mentioned above. Further large scale monoculture of tea plantations has a high impact on the hydrology of the mountainous areas e.g. resulting in large landslides (Fig. 4).

Fig. 4 Landslide in the up country of Sri Lanka, Badulla region (photo Williges, 1998)

About 31 % of the population have access to pipe-borne water and a majority still depends on wells, while 7 % draw water from rivers and reservoirs for domestic use. The large reservoirs provide 90 % of Sri Lanka's electrical energy and irrigate 500,000 hectares of land. Due to the building of vast dams as water reservoirs, several thousand people had to be resettled and micro climatic changes have taken place. Catchment waters running through areas with intensive tea cultivation show significantly high levels of nutrients like nitrite, nitrate and phosphate indicating heavy leaching from agro-chemicals used in the plantation and paddy sector. Salinity of agricultural land increased with large scale cultivation of irrigated gherkins for export and has been reported from isolated patches in major and minor irrigation projects in the dry zone. Eutrification, as the build up of plant nutrients in the soil, is reported from the Nuwara Eliya and

Badulla Districts where intensive vegetable cultivation with high input of artificial fertilizers is taking place (Department of Census & Statistics, 1998 b). In a detailed analysis of land use changes in a highland Uva village of Sri Lanka Starkloff (1998) impressively described how resource competition and land degradation have caused water scarcity, which adversely effects crop cultivation, household production and human health.

Further current issues to be mentioned are wildlife populations threatened by poaching and urbanisation, coastal degradation from mining activities and increased pollution, freshwater resources polluted by industrial wastes and sewage run off as well as waste disposal and air pollution in Colombo (Anonym, 2000).

3 Tea

3.1 Botany

Tea, *Camellia sinensis* (L.) O. Kuntze, belongs to the plant family Theaceae. Today cultivated varieties are hybrids of the original tea plants *Thea sinensis* and *Thea assamica*. For the botanical reference the two extreme varieties *Camellia (Thea) sinensis var. sinensis* and *Camellia (Thea) sinensis var. assamica* are distinguished. The variety *sinensis*, also called China tea, is suitable for growing in marginal areas of the subtropics. It is more drought tolerant and can survive short frost periods. The leaves are small (up to 9 cm long), tough, leathern, with edges, not pointing, with a strong flavour and less yielding (Franke, 1994). The variety assamica, also called Assam tea, is a tropical variety, sensitive against dryness and cold weather conditions. The leaves are big (up to 35 cm long), soft, without edges, pointing, with less flavour and high yielding. Under natural conditions tea grows as an evergreen tree 8 – 15 m tall with a strong taproot growing about 6 m deep.

3.2 Ecophysiological requirements

Tea originated in the highlands of south-west China, Myanmar and north-east India. The natural habitat of tea is the undergrowth of subtropical forests. Today tea is being cultivated between 42° N (Russia) and 27° S (Argentina) longitude, at altitudes ranging from 2200 m right down to sea level. Tea is a crop of wide adaptability and grows in a range of climates and soils in various parts of the world. The minimum annual precipitation considered necessary for the successful cultivation of tea is 1,200 mm, while the optimum ranges between 2,500 and 3,000 mm. Precipitation should be evenly distributed throughout the year. An annual average temperature between 18-20°C is generally considered as ideal for the tea bush. The soil should be deep, well drained and thoroughly aired, nutritious with a low pH (4.5-5.5). Extended drought periods, water logging conditions and temperatures below 12°C and above 30°C are not favourable for the growth of tea.

3.3 Propagation

Tea propagation can be generative by seeds or vegetative by cuttings. Tea plants are referred to as VP (vegetative propagation) or seedlings. Only seedling tea develops an extensive taproot. Seedling tea is said to be less yielding, hardy and does not give a uniform stand because of the heterogeneous source material. The standardisation of an economic method of vegetative propagation (VP) offers a large choice of improved clonal tea varieties. The so-called VP tea has a high yield potential. It is predictable regarding its typical characteristics and it gives a uniform stand but is in general more sensitive and demanding regarding the cultivation than seedling tea. Seeds and cuttings are raised in a nursery under controlled circumstances over a period of 1-3 years. When planted in the field the young tea plant is given a "cut across" at about 23 cm above the soil to encourage lateral growth. Cutting is repeated at different growth stages to provide formation of a bush. The technical term used is "bringing into bearing". Until the first light plucking of young shoots takes place, tea is referred to as immature. Depending on the plants' condition plucking is started in the fourth year and hereafter referred to as mature tea.

3.4 Fertilisation

The high yielding clonal varieties are very demanding regarding the supply of fertilizer. The nutrient uptake from the soil of 4 tons harvested green leaf comes up to 45-60 kg nitrogen (N), 4-7 kg phosphorus (P), 20-30 kg potassium (K) and 4 kg calcium (Ca) per hectare (Rehm, 1989) Following the fertilizer recommendations for conventional tea cultivation considering the location and yield structure, 100-360 kg N, 20-50 kg P_2O_5 and 60-180 kg K_2O per ha a^{-1} are applied as easy soluble mineral fertilizer (TRI, 1986).

3.5 Pruning

Pruning is essentially the artificial removal of the leaf bearing branches of the plant. The operation is aimed at keeping the size and vegetative vigour of the plant in a condition most conducive for maximum vegetative growth and cropping (TRI, 1986). Various styles of pruning can be distinguished. Every 4-5 years deep pruning (30-40 cm height) for rejuvenation and frame sanitation is practised, followed by a period of recovery.

3.6 Plucking

The process of harvesting tea by selective hand picking of tender shoots (up to 30 kg day^{-1} per plucker) is called plucking. Qualified hand picking assures the best quality. The shoots are plucked at regular intervals throughout the year, in general every 4-10 days. The unit harvested consists of the terminal bud, the internodes and 1, 2, or 3 leaves immediately below the bud. Plucking is the most labour intensive and the most expensive field operation in tea cultivation. Plucking machines have been successfully developed to improve labour productivity and bring down production costs. Deployment of machinery is limited due to natural circumstances (steep slopes) and resulting in a lack of quality of the leaf.

3.7 Plant protection

The shot-hole borer *Xyleborus fornicatus* is a small beetle belonging to the family of Scolytidae. It is a primary or key pest and has been regarded as serious for more than 30 years. Although widely distributed in tea growing areas between elevations of about 150 to 1300 metres, severe damage resulting in protracted debilitation of plant frames is generally confined to tea grown between elevations of 600 to 900 metres. Apart from tea, this insect has been recorded on a wide range of other host plants (TRI, 1986). Curtailing the population build up with long persistent insecticides has been a conventional control strategy. Due to the long-term secondary damage, that is the debilitation of primary branches, pruning times have been adjusted to prevent overlapping of the critical period of basal primary branch susceptible stage with the peak borer colonisation period within the year. Further an attempt has been made to control *Xyleborus fornicatus* on the physiological level by developing a metabolic disrupter that could prevent development to maturity.

The red spider mite O*ligonychus coffeae* is one of four Arachnid pests found in tea in Sri Lanka. It is the only species of mites found in tea that spins a fine web of silken threads over the leaf surface. Their outbreaks occur during dry weather. Their attack is mainly confined to the upper surface of the maintenance foliage and could readily be identified by the bronzing of the leaf. Generations overlap completely and all stages of the life-cycle can be found on the upper surface of the maintenance foliage. There are a number of naturally occurring predators such as coccinellid and staphylinid larvae, lace-wing larvae and other predatory mites such as the *Typhlodromus* and *Phytoseius* species preying on mites in tea.

Besides the two pests mentioned above blister blight is the only disease of economic importance in Sri Lanka first recorded in 1946. The fungus *Exobasidium vexans* causes blister blight leaf disease. The fungus causing the disease is an obligate parasite and no alternative hosts next to tea are known. Moisture is the most essential factor required for the infection of tea, being necessary for the germination, production and release of the spore. Exposure to direct sunlight kills the spores of the fungus. This has lead to the removal of shade trees in susceptible areas. Conventional farmers spray copper fungicides.

3.8 Processing

The plucked leaves should be stored in a loose manner and brought to the factory immediately after plucking to avoid leaf damage and uncontrolled fermentation. During processing the leaves undergo many chemical and physical changes. Withering, rolling, fermenting, drying and sorting are the main steps. Depending on the maceration process, referred to as orthodox, CTC (Crushing Tearing Curling) and LTP (Lawrie Tea Processor), different tea qualities are obtained.

3.9 Tea growing in Sri Lanka

“Sri Lanka’s geographic location and topography define the climatic and agro-ecological framework, within which the potential tea growing areas are situated. Practically the whole wet zone as well as a considerable portion of the intermediate zone, especially in the Uva basin and eastern Badulla District, is basically suitable for the successful cultivation of tea” (Humbel, 1991). According to the elevation grown at, tea estates, tea fields and all tea sold in Sri Lanka are divided into three groups:

- High grown or up country >1200 m
- Medium grown or mid country 600 – 1200 m
- Low grown or low country 0-600 m

Linked with this classification is tea quality and yield, seasonality, tea characteristics such as flavour, liquor and colour, tea grades offered for sale and prices fetched.

3.10 History of tea planting

Tea is mentioned in literature as far back as 2000 BC. It was believed that tea had been cultivated for a long time in the hills of Assam until large scale tea planting was started in Indonesia in 1684 and in India at the beginning of the 19^{th} century. In 1839 two hundred and five tea plants of *Camellia sinensis* var. *assamica* were brought from India to the Peradeniya Botanical Garden in Sri Lanka. Two years later tea plants originating from China were planted at Pusselawa. Commercial tea planting began in 1867 after the rust leaf disease *Hemileia vastatrix* had destroyed coffee plantations. James Taylor from Great Britain was the first commercial tea planter in Sri Lanka. Under him, approximately 8 ha at Loolecondera in Hewaheta (near Kandy) were cleared and planted with tea in 1867, which is still in production (Fuchs, 1989). The immense labour requirement for the clearing of virgin tropical rainforest and for the large scale cultivation of tea was saturated by bringing Tamil labourers from South India (Tamil Nadu) to Sri Lanka. In 1873 the first "Ceylon Tea" was exported to London. Sri Lanka was British Crown Land from 1802-1948 and ruled by the British who introduced plantation management and set up the additional infrastructure. Around 1958 the national and socialist movement became stronger. The government officially introduced a plan to nationalise the plantation sector. Foreign investors started to neglect their lands and invested their profits in other tea growing countries like Kenya. In 1972 all private tea plantations, still mainly managed by British agency houses and a few local individuals were nationalised. Mismanagement and corruption continued. After the land reform in 1972/75 a small percentage of the nationalised land was distributed among the Singhalese population for housing and agricultural purposes. "The immediate goals of the land reform defined by the government were to distribute land to the landless, to solve the unemployment problem, and to increase agricultural output. Land distribution as the first goal of the land reform made the program popular and raised high expectations among the landless who constituted, in 1975, approximately 325,000 persons or 20 % of all those employed in subsistence or small market-oriented agriculture in villages" (Humbel, 1991). Under political pressure from the Kandy District through the "village extension program" further land (app. 48,500 hectares) was distributed in small plots of 0.2-0.4 hectares among landless people. It can be assumed that this program was only run out of political motivation in view of the coming up elections in 1977. The plot size was economically inefficient after building a house and vegetable garden to generate an income from the remaining tea area and mainly marginal land with steep slopes was distributed. Further no necessary infrastructure program followed to support the new farmers (extension, marketing, credit system, etc.) (Betz, 1993). “In most cases, the yields on these tea lands have fallen since redistribution, largely due to poor farm management. Only very few villagers have manured their land and pruned the tea bushes properly” (Rote, 1986).

3.11 Tea area changes

The total area under tea cultivation in Sri Lanka constituted 188,967 hectares in 1994. Out of this Tea Small Holdings (TSH) comprised 82,920 hectares (43.88 %) and state-owned Estates 106,047 hectares (56.12 %) (Tab. 3). According to the Department of Census & Statistics in 1982 the total area under tea cultivation was 207,147 hectares. Out of this TSH comprised 67,504 hectares (32.59 %) and state sector estates 139,643 hectares (67.41 %). The above comparison shows an 8.78 % decrease in the extent of the total area grown with tea from 1982 until 1994. This change has been due to an increase of 22.84 % in the smallholdings and a decrease of 24.06 % in the state owned estates (Sri Lanka Tea Board, 1996). The decrease in extent has mainly taken place in the Central Province (Districts of Kandy, Matale and Nuwara Eliya) and the Badulla District in the Uva Province. These were the predominant areas in tea cultivation over a period of 75 years. “The most significant area losses are registered in the Kegalle, Kandy and Matale Districts which all diverted more than 40 % of their earlier tea areas into other land use types. Aubert (1974) cites estimates that 9,000 ha of tea land of estates larger than 40 ha were abandoned and left fallow already in 1970. In addition he speaks of another 11,000 ha of uneconomical tea belonging predominantly to the smallholdings sector. A comparison of tea cultivated area by sectors and districts during the period of 1982/83 and 1994 for Kandy District shows a decrease of 5,892 hectares (37.71 %) of smallholder tea land and a decrease of 5,799 hectares (29.8 %) of state owned estates land.

“A tea land below 10 acres (4.05 ha) with a density of more than 1,000 tea bushes per acre and in possession of an independent cultivator is called a small holding. If the area planted with tea is bigger than 4 ha it is defined as an estate” (Sri Lanka Tea Board, 1996). If the bush density is less than 1,000 per acre the holding is considered as abandoned and not entitled for service and premiums by the Tea Small Holder Development Authority (TSHDA). Following this definition about 70 % of the investigated organic holdings are considered as abandoned tea land.

Tab. 3 General categories of tea production in Sri Lanka (Sri Lanka Tea Board, 1997)

Category	No. of holdings (1994)	Extent under cultivation in ha (1994)	Production 1,000 tons (1997)
Tea small holdings	206,652	82,920 (44 %)	151.2 (54 %)
State owned estates	404	106,047 (56 %)	128.8 (46 %)
Total	207,056	188,967 (100 %)	280.0 (100 %)

Geographically there is a concentration of TSH in the Districts of Galle (21.6 % of the total area cultivated by SH), Matara (20.8 %), Ratnapura (20.5 %) and Kandy (12.4 %), respectively on three low and one medium elevation. The TSHs share on the tea land in the low elevations is higher than the total tea land cultivated by estates. In the low country Districts of Galle, Kalutara, Hambantota, Ratnapura and Matare the area cultivated by tea smallholders increased by 20,000 hectares between 1983 and 1994 (Sri Lanka Tea Board, 1996). The national increase in tea production comes from the low elevation areas and reached 150,000 metric tons (54 % of the national output) in 1998. The high yield level in this smallholder sector is attributed to the fact that almost 100 % of the extent are under young, high yielding, vegetative propagated (VP) tea varieties. Where as in the mid and up country regions large extents of low yielding old seedling tea can still be found (CBS, 1998 a).

The tea smallholder sector is of special importance for Sri Lanka’s economy. More than one million rural residents, or 6 % of the total population, rely on tea growing or processing for their livelihood. This sector has shown a considerable growth over the last two decades and the smallholders share in the national output increased from 54 % in 1997 to 61 % (170,800 t) in 1998. Further the TSH sector is responsible for 70 % of the value of all the tea produced in Sri Lanka. The average yield of the smallholder sector increased by 11 % to 2,192 kg made tea per hectare and year while the yield level in the estate sector has been stagnant at a level of 1,052 kg ha^{-1}. The average national yield of 1,559 kg ha^{-1} is much lower than in other competing countries such as Kenya (2,284 kg ha^{-1}) and India (1,850 kg ha^{-1}) (CBS, 1998 a).

4 Organic Agriculture

Organic agriculture is a holistic approach to sustainable production implementing environmental protection measures and considering social standards. In many countries it is known as ecological or biological agriculture, reflecting the reliance on ecosystem management rather than external inputs. Basically it is a cultivation method excluding the use of chemicals, either as plant protection products or as fertilizers. Main nutrient sources are animal dung, compost, green manure and oil cakes. Several plant extracts can be used for natural pest control. The principle aims of organic agriculture and processing are defined by the International Federation of Organic Agriculture Movements (IFOAM, 1996).

Certified organic agriculture refers to various systems for producing food, feed and fibres according to specific standards, which promote environmental, social and economic health. In order to maintain these standards independent international certification bodies have been established. Inspection and certification work is based on legal country regulations according to the EEC No. 2092/91 or the Swiss Organic Regulation for example and the verification of private standards such as given by Naturland, Biosuisse, Demeter and Bioland.

4.1 World statistics of organic agriculture

Organic agriculture is practised in almost all countries of the world, and its share of agricultural land and farms is growing everywhere. The market with organic products is growing at a fast rate, not only in Europe, Japan and North America (which are the major markets) but also in many other countries, including many so called developing countries. Lack of state regulations for organic agriculture makes it difficult in many countries to distinguish organic from low-chemical or even non-organic products. Official interest in organic agriculture is emerging in many countries. On an international level FAO is giving increasing support to organic farming. Presently the major parts of the organically managed area (24 million hectares world-wide) are located in Australia (about 10 million hectares), Argentina (almost 3 million hectares) and Italy (almost 1.2 million hectares). The share of land area under organic management is however highest in Europe, where the European Union (EU), its six accession countries and the EFTA[1] countries have more than three million hectares under organic cultivation, which is almost two per cent of the total agricultural land. In Latin American countries the organic land area reaches almost 0.5 % and growth rates are extraordinary. In Argentina for example the land under organic management went up from 5,500 hectares in 1992 to 2,960,000 hectares in 2004. For Africa and Asia only a few figures are available. An important factor for growth is the demand for organic products in the industrialized countries (Willer & Yussefi, 2004).

[1] European Free Trade Association

4.2 Literature resources

Next to the statistical compilation of land under organic management Willer & Yussefi (2004) included continent details regarding development, markets, innovations, standards and legislation of organic agriculture in their publication. El-Hage Scialabba & Hattam (2002) published the study “Organic agriculture, environment and food security” looking at the contribution of organic agriculture to ecological health, international markets and local food security also analysing the prospects for a wider adoption of organic agriculture. The primary focus of a report by Parrott & Marsden (2002) was on identifying systems, technologies and methods in organic agriculture systems that are proving effective in increasing yields, eliminating the need for chemical inputs and increasing farmer’s income. Information about “World markets of organic fruit and vegetables” is available from a joint study by the International Trade Centre (ITC, 2001), the Food and Agriculture Organisation (FAO) and the Technical Centre for Agricultural and Rural Co-operation (CTA). With regards to tea the “Handbook organic cocoa, coffee and tea” (FiBL, 2002) was published, giving estimates and insights about the recent market situation of these beverages. More market oriented information is available from ITC (1999), which intends to inform developing countries about the market potential of organic products from their countries for the organic market worldwide. A compendium on “Organic fruit and vegetables from the tropics” (UNCTAD, 2003) covers the production, certification and conditions for market access of organically produced fruit and vegetables in the tropics, addressing producers and international trading companies alike.

4.3 Organic production in Sri Lanka

From 1998–2000 data regarding the organic cultivation of different crops in Sri Lanka was collected personally with a standardised form at the Colombo offices, smallholder organisations and the tea estates. The information was updated through meetings and (e-) mail in 1999 and at the biofair in Nuremberg in 2001. Altogether 15 projects involved in the production of certified organic products could be included in the survey. Historical and background information was gathered through many personal meetings with responsible people from the tea sector, University, government services and at the GSS library. This was the first attempt to structure data about organic farming on country level since no official data was available.

4.3.1 Development, history and recent situation

The organic movement in Sri Lanka started in the 1980s through contact and inspiration of local NGOs with the Philippine organic agriculture movement. In 1982 a group of local NGO representatives, planters, scientists and environmental officers had drafted a Memorandum of Association to create a movement named Lanka Organic Agriculture Movement (LOAM). This can be seen as the official starting point for the dissemination of organic agriculture in Sri Lanka. LOAM was planned to be registered as a company limited by guarantee. The primary objectives of LOAM were to promote organic agriculture, to establish, improve and maintain standards for organic agriculture and to create awareness of organic products among the people of Sri Lanka. Only in 2001 LOAM was registered as an official legal body. Nevertheless activities in the field of organic agriculture continued and evolved to an advanced stage of development, so that particularly two groups can be distinguished. On the one side organic smallholders who are mainly resource poor farmers linked with NGOs. Some have united in producer co-operatives. On the other side large scale organic plantations managed by private owners or as company projects, sometimes associated with surrounding smallholders.

In 1987 the first organic tea estates were certified in Sri Lanka. Today more than 15 projects with a variety of more than 20 crops are involved in growing, processing and trading certified organic products. In 1998 a total of approximately 3,700 hectares have been under certified organic cultivation (Fig. 5).

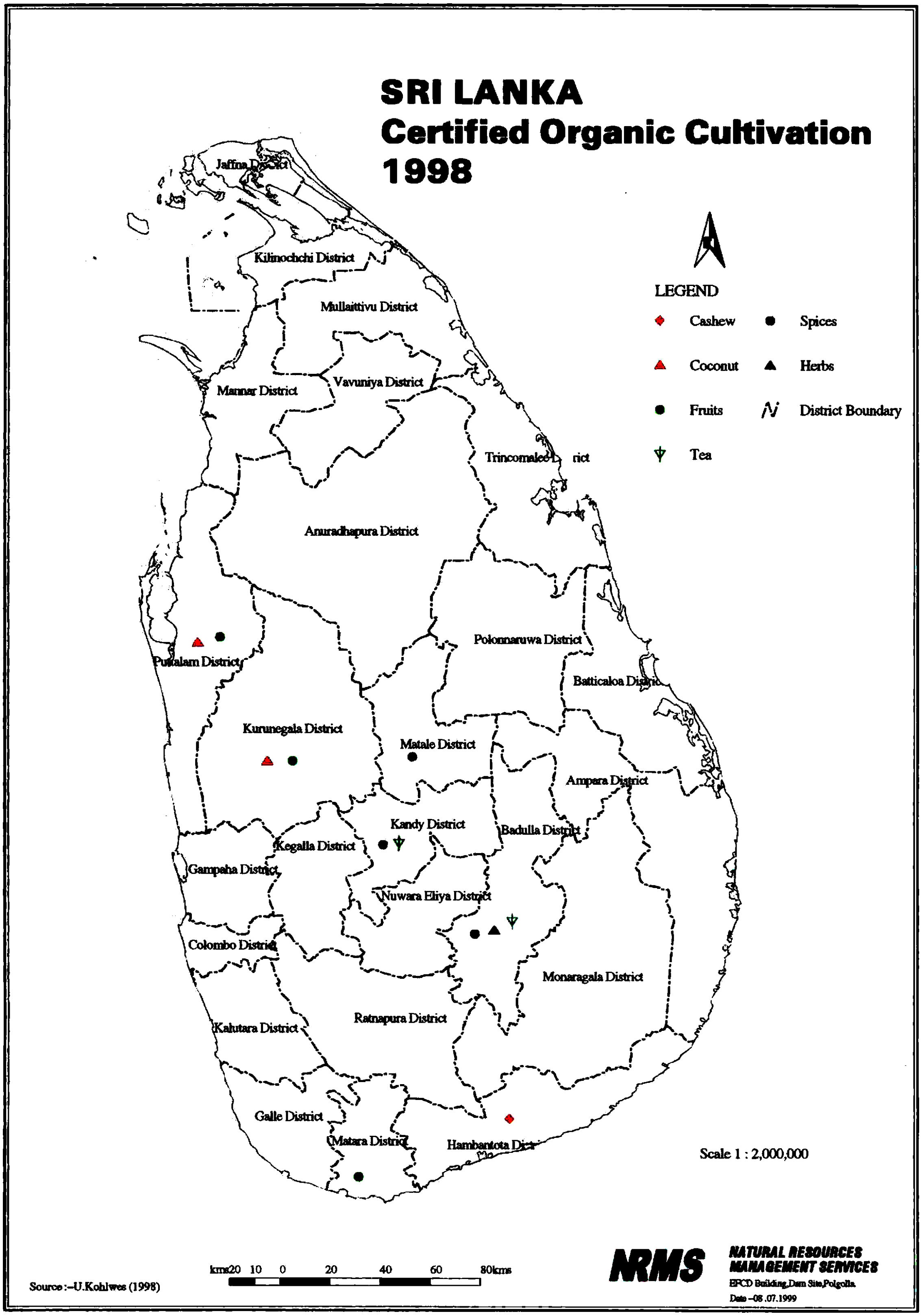

Fig. 5 Locations of certified organic crops grown in Sri Lanka in 1998

4.3.2 Organic crops grown in Sri Lanka

The main certified organic products are tea, desiccated coconut, cashew nuts, spices (cinnamon, cardamom, nutmeg, pepper, clove, ginger), fruit (mango, papaya, passion fruit), and herbs (citronella, lemon grass) (Tab. 4). Most of the products are exported. Major importers are Europe, Japan and Australia.

Tab. 4 Certified organic production in Sri Lanka, 1998

Product	Small Holder (No.)	Estates (No.)	Area (ha)	Production (t)	Yield (kg ha^{-1})	Exported (t)
Black tea	522	6	1140	399.7	130-900	261.7
Green tea*	414	2	490	60.0	350-700	42.0
Cashew nuts	>140	0	142	57.0	440	48.0
Desiccated coconut	>14	0	307	133.3	500 nuts	73.3
Spices	App. 1000	6	300	25.0	-	15.0
Herbs	App. 1000	4	30	10.0	-	5.0
Fruit	App. 1000	4	1814	84.0	-	30.0

Williges & Sauerborn, 2000

*Green tea is seasonally processed from the same area as black tea

Since we are looking at organic production, it has to be recognised that mixed cropping takes place on most of the area. To structure the data separating the area where coconuts, fruit, spices and herbs are grown is difficult. From the 522 smallholders involved in growing organic tea, the harvested leaf of 414 is seasonally processed as green tea. From the six organic tea estates two are seasonally involved in green tea production. More than 1,000 smallholders are involved in the cultivation of spices, herbs and fruit. Part of the spice and herb production is used for the extraction of essential oils. Fruit is mainly processed to juice, juice concentrates and frozen or canned fruit.

Several projects are involved in cultivating different crops in different areas. Tab. 5 gives some project details.

Tab. 5 Certified organic project details from Sri Lanka, 2001

Project	Products	Organic since	Certified by *
Bio Foods (Pvt.) Ltd.	tea, spices, herbs	1998	SKAL
Canela Organica (Pvt.) Ltd.	cinnamon		
Eoas Organics (Pvt.) Ltd.	essential oils: cinnamon, cloves cardamom, nutmeg, pepper, maize, citronella, lemon grass, ginger	1998	IMO, SKAL
Gami Seva Sevana (NGO)	tea	1997	NASAA
Lanka Organics (Pvt.) Ltd.	tea, spices, herbs, forest garden products	1998	NASAA
Maskeliya Plantations Ltd.	tea	1998	IMO, OFG
Need Wood Emmage (Pvt.) Ltd.	tea	1987	IMO
Santushi Basel Ceylon (Pvt.) Ltd.	cashew nuts, spices, fruit		
St. Annes Factory	desiccated coconuts	1997	IMO
Stassen Natural Foods (Pvt.) Ltd.	tea, cashew nuts	1987	IMO
Target agriculture (Pvt.) Ltd.	fruit, spices, herbs, desiccated coconuts, cashew nuts	2001	SKAL
Tea Masters Ceylon (Pvt.) Ltd.	tea, herbal tea		
Watawala Plantations	tea	2000	SKAL

* IMO Institute for Marketecology, Switzerland; NASAA National Association of Sustainable Agriculture Australia Ltd.; OFG Organic Farmers & Growers, United Kingdom; SKAL, Netherlands

Cashew nuts are mainly grown by smallholders in Kurunegele, Chilaw and Hambantota District. In Hambantota District annual precipitation can be as low as 1,075 mm. Water is becoming the limiting factor for land cultivation. Sometimes drinking water has to be carried for several miles or is delivered by a lorry to the homesteads. If the distribution of rain is even cashew nuts can be harvested twice a year. The labour intensive processing is mainly done by contract factories also for quality assurance. In the north-western districts of Kurunegala, Chilaw, Matale and Puttalam organic coconuts are cultivated (by 14 smallholders covering a total area of 307 ha in 1998). The coconuts are collected on a regular basis and stored in a separate area at a contract factory. Sufficient quantities of organic quality coconuts are exclusively processed at certain intervals. After processing they are exported as desiccated coconut to Germany and USA. Smallholders grow spices, herbs and fruit in mixed cropping systems and on plantation level. Next to their natural use they are processed as essential oils, fruit juice, juice concentrates, dried and canned fruit. With a production of approximately 400 t covering an area of more than 1,000 ha black tea of orthodox quality was the major organic crop with an export value of app. 3.2 million US $ in 1998. The organic green tea production is a demand driven recent development with seasonal fluctuations.

4.3.3 Certification

So far no local certification body has been established on the island itself. International certification organisations like NASAA (National Association of Sustainable Agriculture Australia Ltd.), IMO (Institute for Marketecology, Switzerland), OFG (Organic Farmers & Growers, United Kingdom) and SKAL (Netherlands) are sending inspectors to carry out the certification procedure. In 1998-99 representatives from SKAL and IMO have been present in Sri Lanka as residents carrying out inspection work from a local office cutting down inspection costs. Nevertheless national activities have been started and some locals have participated in inspection seminars overseas allowing them to get involved in the internal monitoring system of organic projects in Sri Lanka.

4.3.4 Official recognition

No government policy or support system like conversion grants have been adopted so far, but the government officially began to recognise the organic agriculture movement inside the country. In 1999 the Export Development Board initiated a meeting with responsible people involved in growing, trading and research about organic agriculture and discussed the possibilities of increasing smallholders organic spice production in quality and quantity. Further the Export Development Board regularly participates at the Biofair in Nuremberg, Germany, the world's largest trade fair for organic products, and facilitates representatives from organic projects to exhibit at the country stall.

Educational and advisory activities are gradually expanding. The Environment and Forest Conservation Division, Mahaweli Authority of Sri Lanka, plays a major role in awareness, training and mobilisation of soil, water and vegetation conservation especially related to land use and hydrology. Within this context a demonstration farm for environment friendly cultivation is run on organic principles. The Horticultural Crop Research & Development Institute (HORDI), Department of Agriculture, Peradeniya has been involved in studies about the organic cultivation of vegetables and the use of neem (*Azadirachta indica*). The Post Graduate Institute of Agriculture (PGIA), University of Peradeniya has developed a course on organic agriculture, which is included in the curriculum for the year 2000. It is planned to teach the principles of organic farming and growing, to offer short courses on special issues and dissertation projects.

In the field of research and development the Tea Research Institute (TRI) of Sri Lanka has taken steps to include experimental work regarding organic tea production in their activities. In 1999 a mature tea field of 1.2 ha was planned to be converted to organic cultivation for research purposes at the main Estate St. Coombs in Talawakele. Previously some scientists from TRI were involved in studies on existing organic sites mainly related to actual problems occurring in the field like nutrient deficiencies and pest problems. Further there are several NGO's like "Future in our hands", "PALM Foundation", "Gami Seva Sevana" and "Nagenahiru Development Foundation" throughout Sri Lanka involved in advisory services regarding organic agriculture practices and the maintenance of organic farms. GSS as one of the pioneers in organic agriculture in Sri Lanka maintains a library with an extensive collection of books, magazines and brochures regarding all subjects connected with organic agriculture and related fields. All this indicates the developing interest in the dissemination of information within the organic sector.

Part II Tea production systems

5 From subsistence farming to market production: Present role and future potential of the smallholders organic tea cultivation system in the mid country of Sri Lanka

5.1 Introduction

Sri Lanka is one of the smallest but biologically most diverse countries in Asia recognised as a biodiversity "hot spot" of global importance that requires protection. The country has the highest biological diversity (number of species per unit area of land) among all Asian countries in terms of flowering plants and all vertebrate groups except birds (Gunatilleke & Gunatilleke, 1990; National report, 1991). With a growing population and changing trade policies additional land was taken for intensive agricultural and industrial use at the cost of the natural forest. Forest cover decreased from about 80 % in 1900 (Department of Census and Statistics, 1998 b) to 20 % (EIU, 1997) in 1992. Commercial tea planting began 1867 in the mid country of Sri Lanka at Loolecondera in Hewaheta near Kandy and has played a major role in deforestation and loss of biodiversity. It was introduced and established by the British as a plantation crop. Cultivation spread throughout the mid and up country, where agro-ecological conditions for tea are very favourable, by clearing large areas of virgin tropical rain forest. After independence in 1948 the Sri Lankan government planned to partly nationalise the plantation sector to gain local control of the economy. In the early seventies of the 20th century the nationalised plantations were managed by newly formed bodies, the Janatha Estates Development Board (JEDB) and the State Plantations Cooperation (SPC). After exploitation of several plantations in the mid country region through plantation mismanagement tea cultivation became unprofitable and left degraded soils on eroded slopes. Through government programs (village expansion program 1975 ff) and land reforms parts of this nationalised land in the mid country were distributed among the population or converted into tree plantations (*Pinus caribae, Eucalyptus grandis*) (Betz, 1993).
At the research area several investigated farmers have settled due to land reforms and governmental programs. Since 1973 former landless tamil plantation labourers in Nillambe received plots from unprofitable tea plantations. Between 1980-85 Gampola rice farmers had to be resettled after flooding the Kotmale dam. Some wanted to stay in the area and received plots of former tea plantation land with the remaining old seedling[2] tea bushes. Only "a tea land below 10 acres (4.05 ha) with a density of more than 1000 tea bushes per acre and in possession of an independent cultivator is called a smallholding" (Sri Lanka Tea Board, 1996) and entitled for service and premiums by the Tea Small Holder Development Authority (TSHDA). Since the

[2] Teabush grown from a seed with high genetic diversity compared to vegetative propagated (VP) teabushes grown from clonal cuttings of a motherbush

majority of resettled farmers were not officially considered as a tea small holding, excluding them from service and premiums, most of them did not maintain their gardens and harvest their tea bushes on a regular basis. Because of a lack of experience in tea cultivation, weak infrastructure and low prices paid for the green leaf there was no incentive to get into tea cultivation. Income generation was achieved through off farm employment, keeping a low standard of living. But market access is a key point for economical progress of poor farming households and rural development in third world countries. Better market access promotes more efficient allocation and use of resources leading to increased productivity (Hau & von Oppen, 2001; von Oppen et al., 1996). To increase the income producing capacity of rural villages, as a means of poverty alleviation and empowerment of the rural poor projects like the "Export production village" (Tillekeratne, 2001), "Analogue forestry" (Senanayake, 1997) and "Small holders organic tea cultivation" can be found in Sri Lanka.
Considering the international market situation over the past decade, world tea consumption has increased at an annual growth rate of 1.4 %. Developing countries account for the largest part of the increase, with internal consumption rising at an average annual growth rate of 2.1 % (FAO, 2003). In 1999 the home consumption of the tea growing countries (like India 668,000 t, China 448,000 t, Turkey 160,000 t, Japan 81,000 t) constituted 57% of the world black tea production. The remaining 43% (about 1.3 million tonnes) served world export markets (Österreichisches Tee-Institut, 2001). While demand for conventional tea was declining on the international level, the market for organic tea has been growing since its introduction in the late 1980's. Global consumption of organic tea has shown a 10% growth during the last decade. Organic tea production in India, as the largest producer, increased from 150 t in 1990 to 3,000 t in the year 2000 (Muraleedharan, 2001). With a production of approximately 400 t covering an area of more than 1,000 ha (1998) black tea of orthodox quality with an export value of 3.2 million US $ was the major organic crop in Sri Lanka (Williges & Sauerborn, 2000).
This study investigated a group of poor and isolated farmers from the mid country of Sri Lanka, Kandy District, Udapalatha Secretarial Division, which successfully developed plots of degraded former tea plantation land into productive and diverse home gardens by adapting organic agriculture practices. Here, former subsistence production was overcome by means of the concentration on the organic cultivation of tea as a cash crop facilitating market access. Direct marketing of an organic product to a sophisticated European market served as a pillar for further local development. Assessment of farm inventory brought out a variety of other crops demanded on local, regional, national and international markets. Farmers have been guided and supported by two organisations engaged in organic agriculture practices and socio-economic development of tea smallholders. Compliance with international organic and fair trade rules and regulations guarantees products of high quality for the consumer and adequate prices for the farmer. Consumer's willingness to buy organic products supports the smallholders cultivation system. High consumer standards in the organic context are linked to the producer's environmental

awareness, influencing the decision-making process and intensity of production in a sustainable way.
So far research focusing on smallholders organic tea cultivation is limited. Hence the objective of this study was to describe and analyse the mid country organic smallholders production system, focusing on the role of organic tea cultivation to overcome subsistence production and gain market access while maintaining biodiversity.

5.2 Material and methods

5.2.1 Natural conditions of the research area Udapalatha

The Udapalatha Secretarial Division of Kandy District is situated in the mid-country "wet zone" wm2, covering an area of 182 km^2 (Department of Census & Statistics, 2002 b). The climate is characterized by the predominance of the monsoons during 7.5 months of the year with annual precipitation ranging from 2,150 to 3,800 mm (Department of Agriculture, 1981) and average temperatures between 21-24°C (Domrös, 1976). Most of the area was situated at an elevation between 700 – 1000 m above sea level. The major soil group in the area was red yellow podzolic soil with a pH around 6 at the research site. The climate and soil in this region are favourable for the cultivation of tea (*Camellia sinensis*) and other perennial crops like pepper (*Piper nigrum*), cloves (*Syzygium aromaticum*), nutmeg (*Myristica fragrans*), coffee (*Coffea arabica*), coconut (*Cocos nucifera*), fuel and timber tree species like jackfruit (*Artocarpus heterophyllus*) and mahagony (*Swietenia macrophylla*).

5.2.2 Field study

Over a research period of two years (November 1997 – October 1999) data was collected from 529 tea smallholders (TSHs) engaged in organic farming. Out of the 529 tea smallholders 108 were organised under a NGO named Gami Seva Sevana (GSS). Since 1981 GSS is running a rural service centre with a demonstration farm in a region where former intensive tea cultivation has left degraded soils and eroded hillsides. GSS is involved in rural and social development including the promotion of organic agriculture. The remaining 421 TSHs produce under similar conditions for a private company named Bio Foods Ltd. Organic Tea and Spices, dedicated to process and market exclusively organic products. The organic tea production projects officially started in 1995 and had to pass a two year conversion period following organic agriculture principles before being certified as organic in 1997. Both groups were situated in the mid country region, Central Province, Kandy District, Secretarial Division Udapalatha[3].
Both groups enabled the use of their database regarding number of farmers engaged in organic farming, locations, size of the land and monthly yield levels of tea. For economical calculations of the provided data only farmers with available harvest figures from at least 9 months per year

[3] Kandy District is divided into 16 Secretarial Divisions, functioning as organisational units.

(GSS) were considered and acreage accounted only when harvest took place (Bio Foods). Out of the 529 registered organic farmers 507 could fulfil these basic requirements and were used for economic calculations. Further general data regarding ethnic group of the farmer, tea variety cultivated, number and kind of animals kept were ascertained from the whole group of 529 organic farmers.

Out of the 529 organic TSHs more than 100 were visited in different regions and additional detailed information regarding the structure of the garden, plucking and maintenance of tea, animal husbandry practices and the production of other crops were extracted through field observation and discussions. More detailed information was collected from 23 organic farmers through semi structured open questionnaires and personal observation. Here the main attention was directed to agricultural practices like compost making and application, availability of animal fodder, soil and water conservation measures and plant species diversity. Value estimation of already sold plant species for economical calculation (Tab. 6) was done with the farmer's actual data. Remaining species not yet sold on a regular basis were calculated with a symbolic price of 1 Sri Lankan Rupee[4] (SL Rs) per unit. Further details about the tea production system like age of the tea plants, bush density of the tea field, pest problems, the planting material, method and infillings were recorded. A land map was drawn from every holding indicating the set up of buildings, stables, water sources, pathways, plant and tree species.

Most of the investigations took place with the support of the extension staff of the respective group since translation from sinhala or tamil was necessary. All data was gross checked and supplemented with support of the extension workers, farmer group leaders and through personal visits.

This method of data collection, from a general characterisation of a large group of 529 organic tea smallholders to a detailed description extracted from 23 organic tea smallholders, evolved during the research period and made it possible to gain an in depth insight about the organic cultivation system.

Information relating to the subjects of processing, marketing, infrastructure, inspection, certification and extension were collected through the organisational unit of the respective group. The author was in a position to accompany the green leaf collection, visit factories and packaging units, gain insight and get involved in the process of inspection and extension work.

[4] 74,- Sri Lankan Rupees equal 1,- Euro (1998); 64.59 SL Rs equal 1,- US$ (1998)

Tab. 6 Number and estimated economical value of 78 identified plant species at 23 organic tea smallholder sites on a total area of 10.5 ha in Kandy District, Sri Lanka in 1998

Botanical name	Family	English name	Local name	Usage	No. of plants	Unit value SL Rs
Anacardium occidentale	Anacardiaceae	Cashew	Cadju	Nut	6	500
Ananas comosus	Bromeliaceae	Pineapple	Annasi	Fruit	134	25
Annona spp.	Annonaceae	Annona	Anoda	Fruit	33	80
Anthurium spp.	Araceae	Anthurium	Anthurium	Ornamental	50	1
Areca catechu	Arecaceae	Betelnut	Puvak	Narcoticum	451	90
Artocarpus altilis	Moraceae	Bread fruit	Del	Vegetable	20	150
Artocarpus heterophyllus	Moraceae	Jack fruit	Kos	Fruit, vegetable	272	100
Asparagus racemosus	Liliaceae		Hatawariya	Medicinal	4	1
Azadirachta indica	Meliaceae	Neem	Kohomba	Medicinal	1	1
Caereya arborea	Lecythidaceae		Kahata	Fuel, veg., med.	10	1
Camellia sinensis	Theaceae	Tea	Te	Beverage	22907	
Cananga odorata	Annonaceae		Wanasapu	Timber, ornament.	46	1
Canarium zeylanicum	Burseraceae		Kekuna	Timber, fruit	1	1
Capsicum spp.	Solanaceae	Chilli	Miris	Spice	107	30
Carica papaya	Caricaceae	Papaya	Papol	Fruit	50	80
Caryota urens	Arecaceae	Toddy palm	Kitul	Honey	97	800
Ceiba pentandra	Bombacaceae	Kapok		Fibre	14	100
Chrysophyllum cainito	Sapotaceae	Star apple	Laulu	Fruit, med.	1	1
Cinnamomum verum	Lauraceae	Cinnamon	Kurundu	Spice	20	150
Citrus aurantium	Rutaceae	Sour orange	Ambol dodam	Fruit, med.	2	1
Citrus limon	Rutaceae	Lemon	Lemon	Fruit	29	100
Citrus maxima (grandis)	Rutaceae	Grape fruit	Jambola	Fruit	16	1
Citrus reticulata	Rutaceae	Mandarin	Naran	Fruit	18	1
Citrus reticulata	Rutaceae	Mandarin	Naran	Vegetable	1	1
Citrus sinensis	Rutaceae	Sweet orange	Pani dodam	Fruit	28	1
Cocos nucifera	Arecaceae	Coconut	Pol	Nut	112	100
Coffea arabica	Rubiaceae	Coffee	Kopi	Beverage	919	40
Colocasia esculenta	Araceae	Taro	Kiriala	Vegetable	50	25
Coriandrum sativum	Apiaceae	Coriander	Kottamalli	Spice	1	1
Curcuma domestica	Zingiberaceae	Turmeric	Kaha	Spice	1259	10

Dendrocalamus giganteus	Poaceae	Bamboo	Una	Multipurpose	1	1
Dioscorea spp.	Dioscoreaceae	Yam	Wel ala	Vegetable	5	25
Elaescarpus serratus	Elaeocarpaceae	Ceylon Olive	Veralu	Fruit	7	50
Elettaria cardamomum	Zingiberaceae	Cardamom	Caradhamungu	Spice	5	20
Erythrina variegata	Fabaceae	Indian cord tree	Eramudu	Fuel, fodder	2	1
Eucalyptus spp.	Myrtaceae		Terpentine	Fuel, timber	7	1
Fillicium decipiens	Sapindaceae		Pihimbiya	Fuel, timber	10	1
Flacourtia ramontchi	Flacourtiaceae	Ramontchi	Uguressa	Fruit	2	1
Garcinia cambogia	Clusiaceae		Goraka	Vegetable	2	1
Garcinia mangostana	Clusiaceae	Mangosteen	Mangus	Fruit	2	1
Gliricidia sepium	Fabaceae	Quick stock	Giniceria, Makulatha	Multipurpose	254	1
Grevillea robusta	Proteaceae	Silver Oak	Sabukku	Fuel, timber	27	1
Justicia adathoda	Acanthaceae	Adathoda	Kalu weraniya	Medicinal	3	1
Lasia spinosa	Araceae		Kohila	Vegetable	25	1
Litsea glutinosa	Lauraceae		Bomi	Fuel, med.	1	1
Mangifera indica	Anacardiaceae	Mango	Amba	Fruit	65	700
Michelia champaca	Magnoliaceae	Champak	Gini sapu	Fuel, timber	53	1
Moringa oleifera	Moringaceae	Drum stick	Murunga	Vegetable	2	15
Musa spp.	Musaceae	Banana	Kesel	Fruit	115	120
Myristica fragrans	Myristicaceae	Nutmeg	Sadikka	Spice	3	100
Neolitsea fuscata	Lauraceae		Kududawula	Fuel, timber	16	1
Nephelium lappaceum	Sapindaceae	Rambutan	Rambutan	Fruit	8	100
Pandanas amaryllifolius	Pandanaceae	Rampe	Rampe		3	1
Passiflora edulis	Passifloraceae	Passion fruit	Wel dodam	Fruit	14	80
Persea americana	Lauraceae	Avocado	Aligata pera	Fruit	52	100
Phyllanthus emblica	Euphorbiaceae	Emblic	Ambula	Fruit	14	1
Piper betel	Piperaceae	Betel leaf	Bulath	Stimulans	6	30
Piper nigrum	Piperaceae	Pepper	Gammiris	Spice	1105	30
Pouteria campechiana	Sapotaceae		Lavulu	Fruit	2	1
Psidium guajava	Myrtaceae	Guava	Pera	Fruit	66	100
Pterocarpus marsupium	Fabaceae	Gumtree	Gammalu	Timber	85	1
Punica granatum	Punicaceae	Pomegranate	Delum	Fruit	7	100
Ruta graveolens	Rutaceae	Garden Rue	Aruda	Med., ornam.	3	1
Saccharum officinarum	Poaceae	Sugarcane	Uk gas		1	1
Sesbania grandiflora	Fabaceae	Corkwood tree	Kathurumurunga	Vegetable	52	260
Solanum surratense	Solanaceae		Thalana batu		10	1

Spondias dulcis	Anacardiaceae	Jamaica plum	Ambarella	Fruit	2	1
Swietenia macrophylla	Meliaceae	Mahagony	Mahagony	Timber	2	1
Syzygium aromaticum	Myrtaceae	Cloves	Karabu nati	Spice	196	260
Syzygium caryophyllatum	Myrtaceae		Dan	Fruit	1	1
Syzygium jambos	Myrtaceae	Rose apple	Jambu	Fruit	3	50
Tamarindus indica	Fabaceae	Tamarind	Siyabala	Fruit	12	200
Terminalia arjuna	Combretaceae		Kumbuk	Fuel, timber	8	1
Theobroma cacao	Sterculiaceae	Cacao	Cocova	Beverage	32	50
Toona ciliata	Meliaceae	Indian mahagony	Tuna	Timber	72	1
Vanilla planifolia	Orchidaceae	Vanilla	Vanila	Spice	7	100
Vitex negundo	Verbenaceae		Nika	Medicinal	2	1
Zingiber officinale	Zingiberaceae	Ginger	Inguru	Spice	250	1

5.3 Smallholders organic tea cultivation in 1998 – survey results

5.3.1 Group details of organic tea smallholders

In 1998, after a conversion period of two years, 14 % of all TSHs situated in Udapalatha Secretarial Division of Kandy District grew certified organic tea on an area of 255 ha (10.6 % of TSH land) (Fig. 6). Many of these smallholders did not harvest their tea and maintained their garden before joining the organic projects, so that plots of former tea plantation land had naturally developed into early succession stages of home gardens with a marginal degree of self subsistence. Incentive to convert and intensify a diverse cultivation system was given by Gami Seva Sevana (NGO) and Biofood Pvt. Ltd. (company) providing extension service, collection of crops, premium green leaf prices, processing and packaging facilities, marketing, certification, export arrangements and infrastructure (office, library, seminars, vehicles, official contacts) through contract farming. Tab. 7 gives some characteristic details about the two investigated groups.

Tab. 7 Group details of 507 organic tea smallholders (TSHs) investigated in 1998 at Udapalatha, Kandy District of Sri Lanka

Details	Tea Small Holder Groups	
	Bio Food Pvt. Ltd.	Gami Seva Sevana
No. of farmers	416	91
Area under tea (ha)	192.8	42.7
Green leaf harvest (kg a^{-1})	306,432	26,984
Green leaf yield (kg ha^{-1} a^{-1})	1587	724
Made tea yield (kg ha^{-1} a^{-1})	396	181
Size of TSH (ha)	0.46	0.47
Green leaf price (SL Rs kg^{-1})[1]	30	27
Monthly income from tea (SL Rs)	1841	677
Tea stand	64 % Seedling 36 % VP[2]	>80 % Seedling
Processing facilities	Own factory	Contract factory
Farmers ethnic	98 % Singhalese	77 % Singhalese, 23 % Tamil
Farmers rearing animals	< 45 %[3]	37 %

[1]SL Rs = Sri Lankan Rupees (64.59 SL Rs equal 1,- US $ 1998)
[2]VP = vegetative propagated; [3]estimated

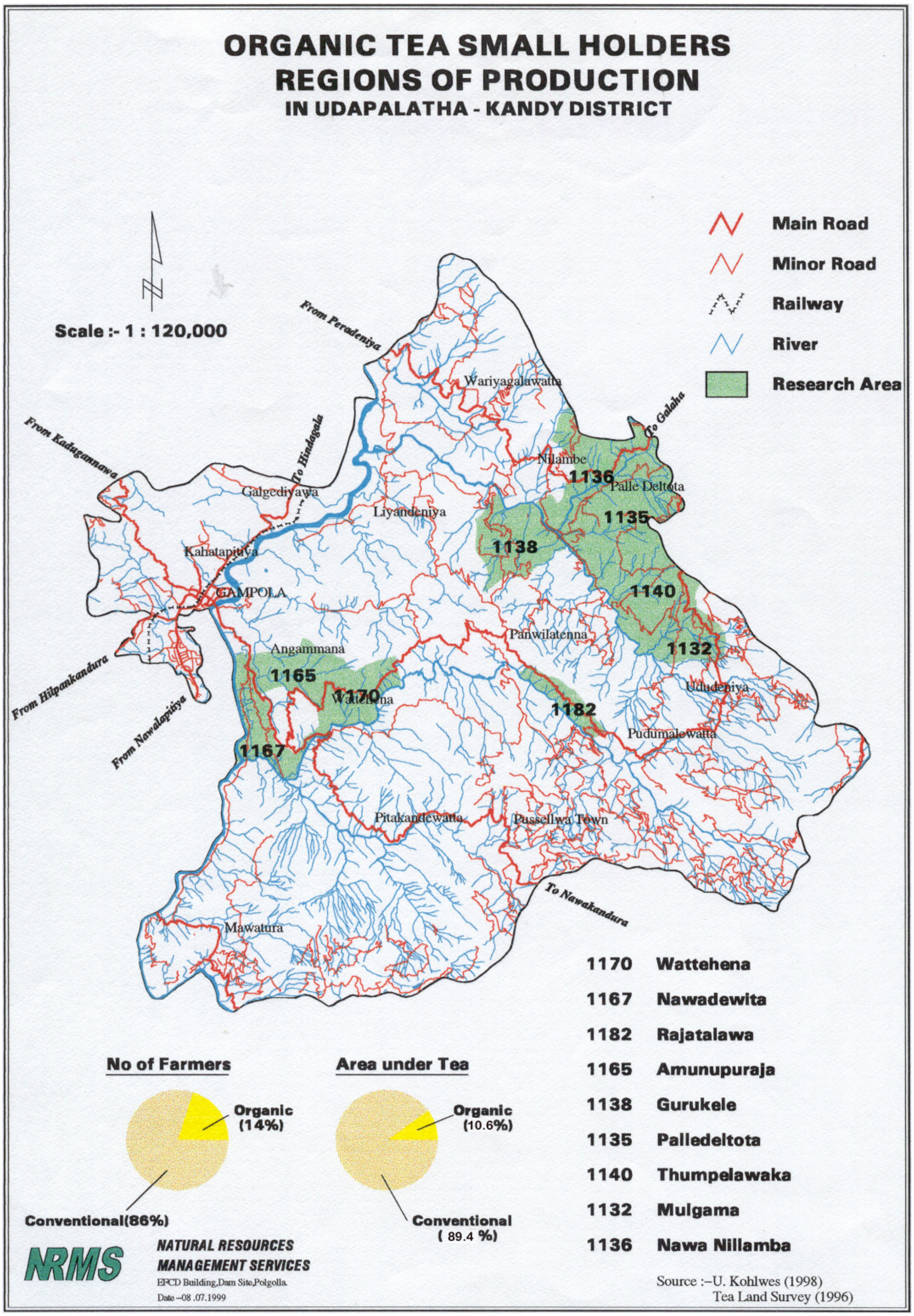

Fig. 6 Organic tea smallholders regions of production in Udapalatha, Kandy District of Sri Lanka

5.3.2 Plant production system

All of the surveyed gardens were found on slopes with a gradient between 5 and 30 % and an average size of 0.46 ha. 92 % of the organic tea smallholders cultivated plots of former tea plantation land with a given agricultural structure (Fig. 7). On 70 % of the holdings old seedling tea was grown (>50 years old). About 30 % of the farmers cultivated more than 2430 bushes per hectare and were officially recognised as a tea smallholding. About 80 % of the tea plots had a high vacancy rate, a low bush cover density and an uneven plucking table. Besides tea, 77 plant species of economical value were recorded at 23 organic TSH sites (Tab. 6). Plants like coffee, fruit-, palm- and timber trees were grown as well as spices and shrubs.

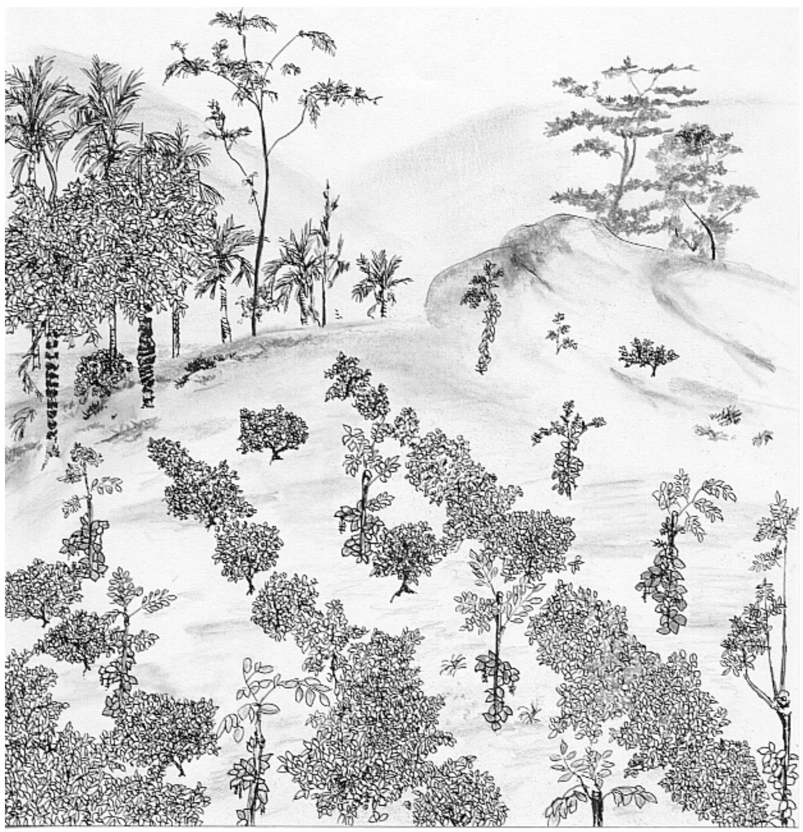

Fig. 7 Organic tea smallholder site in Kandy District, Sri Lanka

Entering the area small pathways led from the main road to the gardens. Most of these pathways were narrow, steep and winding and not suitable for cars and trucks. The pathway to the house and the yard are kept free of vegetation. The place is used to dry seeds, grains, herbs and laundry. Another functional advantage is that especially snakes find no shelter to enter the house. In the vicinity of the main building but in different directions are a small outhouse, a well or water source and a stable or shed for animals. Around the yard ornamental plants like the temple tree (*Plumeria* sp.), jasmin (*Trachelospermum jasminoides*), hibiscus species and *Ixora coccinea* are arranged. Near the kitchen light demanding herbs and spices for cooking like curry pincha (*Murraya koenigi*), chillie (*Capsicum frutescens*) and turmeric (*Curcuma longa*) are grown. Further fruit like papaya (*Carica papya*), citrus species, guava (*Psidium guajava*), mango (*Mangifera indica*), annona species and passion fruit (*Passiflora edulis*) can be found around the house. Vegetable cultivation is limited due to the high incidence of natural enemies like wild boars and monkeys frequently exploring the gardens. In protected areas eggplants (*Solanum melongena*), okra (*Abelmoschus esculentus*), *Luffa aegyptiaca*, *Momordica balsamina*, chayote (*Sechium edule*), winged beans (*Psophocarpus tetragonolobus*) and spinach (*Basella alba*) are cultivated.

Tea bushes dominate the remaining part of the garden. Replanting and infilling is preferably done with approved and recommended vegetative propagated (VP) clones by the TRI like T 2023 and T 2025 which are high yielding and in the case of T 2025 drought tolerant and nematode (*Pratylenchus loosi*) resistant, but difficult to establish in the nursery. So far tea plants and cuttings from approved clones are purchased from the Tea Research Institute and several tea estates. Some older farmers prefer so called estate clones, which are more adapted to specific agro-climatic regions, or clones with a vigorous growth producing high quality tea. Two farmers told to collect seeds from their own vigorous tea bushes to fill vacancies in a natural way by placing the seed without any special care. If germination takes place the seedling is raised appropriately. Recently farmers are being advised in building their own nursery and raising organic tea plants.

The appearance of shade trees is not uniform. Older shade trees (>15 years) belong mainly to the *Albizzia* sp. and *Cassia* sp.. Recently *Gliricidia sepium* was introduced and gained broad acceptance as a multi purpose tree used for shade, fodder, mulch material and as a supporter for pepper vines (*Piper nigrum*). Farmers told to be satisfied with gliricidia because it allows several cuttings without dying back and it is easy to establish through cuttings.

In vacant patches and rocky areas throughout the garden several tree species developed naturally. Depending on their type and usefulness after establishment they will prosper and grow or be cut. Due to religious attitudes some species are regarded as sacred like *Artocarpus heterophyllus*, *Ficus religiosa*, *Ficus benghaliensis* and therefore protected and present in almost every garden. *Syzygium aromaticum*, *Tamarindus indica*, *Piper nigrum*, *Coffea arabica*, *Nephelium lappaceum*, *Garcinia mangostana*, *Persea americana* and *Artocarpus altilis* are often exchanged between villagers and handled with care. Mainly saplings of *Musa* sp. and *Cocos nucifera* are regularly bought from outside and raised with special attention. To mark the borders of the garden species like *Areca catechu*, *Bambus vulgaris*, *Erythrina variegata*, *Ceiba pentandra* and *Caryota urens* are preferably used. Several footpaths lead throughout the garden and steps are built on steep slopes. Water, firewood, animal fodder and harvested goods are mainly carried on the head.

5.3.3 Animal husbandry

One principle aim of organic agriculture is to encourage and enhance biological cycles within the farming system involving animals for organic manure production (IFOAM, 1996). Lack of fodder material during the dry season is one main limiting factor for animal husbandry in the research area. Small scale dairy farming is being supported by government projects and non government organisations (NGOs) in order to improve the household income, nutritional diet and soil fertility. Animal husbandry can be found on less than 40% of the organic holdings. Cattle, buffaloes, goats and chicken are kept in different numbers per household, cattle and goats being the most important groups. Buffaloes are only kept by farmers cultivating tea and paddy. Some farmers worked as day labourer ploughing paddy fields with their buffaloes. Women are involved in the production and selling of curd from buffalo milk. Cows are mainly kept for dairy production with a milk yield of 3–8 litres per day depending on the breed. Milk is sold to milk collecting centres in the vicinity (up to 5 km) of the farms for 9 SL Rs per litre in 1998. If 4 litres of surplus milk per day were sold for 9 SL Rs litre^{-1} about 7,560 SL Rs are earned over a period of 210 days. Mainly Jerseys, Frisians and local cross breeds can be found. Controlled mating once a year by insemination is practised (depending on the breed, 75-200 SL Rs fee for a successful service).

Fodder management can be described as a cut-and-carry system of grasses and leaves. Sometimes controlled grazing in the forest or stubble grazing on paddy fields is done. Additional feeding of coconut cake (poonac), rice bran, concentrates and salt is practised. Disease control is done with local medicine. In severe cases farmers can call the veterinary service in awareness of the high rates being charged. Mastitis, seasonal coughing and parasites were the main observed problems. Manure is used in the home garden, sometimes for the kitchen fire and occasionally sold to other villagers.

Goats are kept in a fenced paddock with a wooden platform on stilts with a wooden or thatched roof and without a solid wall. Fodder is supplied by the cut-and-carry system. Controlled mating by insemination is practised with 2-3 offsprings per year where male goats are not available (20-50 SL Rs fee per service). Goats are mainly kept for meat production and sold alive to a (very often Muslim) butcher. Animals in general are sold when money is needed to cover special expenses like school fees, funerals or social obligations.

Chickens are kept under backyard conditions in sheds made out of clay during the night and free ranging possibilities during the day. Country chickens are hatched for home consumption of eggs and meat. Broiler production in the organic context is limited due to the unavailability of adequate organic grains.

5.3.4 Manuring

Major problems mentioned by the farmers were low soil fertility due to erosion and scarcity of organic materials. To maintain and improve soil fertility with organic amendments requires skill, is time consuming and work intensive, to import organic material is very costly. Efficient recycling through composting was mainly implemented by TSHs rearing animals. Without animal manure composting is less effective and not easily accepted by farmers. Compost heaps were built in the vicinity of animal sheds. Compost and animal dung was preferably given to pepper vines. It could be observed that only a few farmers were producing a sufficient quantity to manure their tea plants with compost. Then the compost material was spread lose underneath the tea bushes. Sometimes quantities did not exceed one handful per bush in order to reach all plants. Manuring schedules have not yet been utilised by many farmers. After deep pruning of the tea bushes some farmers are incorporating the pruning material in 15-20 cm deep trenches between the tea rows together with compost or animal dung once in four years. So far faeces from conventional broiler and layer production have been used for organic vegetable and tea production after undergoing an intensive composting process.

N-accumulation through legumes was another technique adopted to optimise soil fertility. If the farmer did not rear animals, herbs, grasses and leaves of *Gliricidia sepium* were mulched. *Arachis pintoi* was successfully introduced as a cover crop in weak tea plots and along the borders or pathways of several gardens. After a slow establishment period it is a fast growing creeper. Planting of well established plants from pots into the field assured quick soil cover and effective weed suppression. *Arachis pintoi* is a shade tolerant and durable legume. Further there was natural litter fall from shade and bordering trees. Gotukola (*Centella asiatica*), *Oxalis corniculata* and *Desmodium heterophyllum* were tolerated as soft weeds for ground cover. There was still a habit of burning grass patches and leaf litter to keep the garden clean.

5.3.5 Plant protection

Most of the farmers interviewed reported not to have severe problems regarding pests and diseases. Several farmers mentioned having occasional problems with blister blight (*Exobasidium vexans*) and red spider (*Oligonychus coffeae*). Only a few farmers mentioned having serious problems with the shot-hole borer (*Xyleborus fornicatus*).

The shot-hole borer *Xyleborus fornicatus* is a small beetle belonging to the family Scolytidae. Organic farmers are advised to prune the infested bushes and carefully collect and burn the cuttings. A neem (*Azadirachta indica*) kernel solution is sprayed on the branches and neem cake incorporated in the soil around the bush. If infestation is serious and the bush weak, uprooting and burning is recommended as well as careful soil rehabilitation before replanting with tea. The red spider mite *Oligonychus coffeae* is one of four Arachnid pests occurring in tea in Sri Lanka. Organic farmers are advised to spray neem in affected pockets starting from an outside circle moving inwards to the centre.

5.3.6 Processing, marketing, infrastructure

The average TSH is not in a position to use infrastructure in order to market his own tea leaf. In general TSHs depend on transport and processing facilities mainly provided by neighbouring tea estates or licensed dealers. Because of this the price for green leaf can be very low and subtractions for wet or coarse leaf are sometimes arbitrary and unpredictable. Both organisations provide the infrastructure to collect, process, pack and export the organic made tea accompanied by a sophisticated extension service.

Gami Seva Sevana process their leaf in a contract factory. Once a week on a set day a lorry provided by the organisation collects the leaf from several collecting points. The leaf is brought to the factory the same day and spread out on dryer tables. This day the factory staff thoroughly cleans the processing units after finishing the conventional leaf processing to avoid contamination of the organic quality leaves. Next days production starts with the orthodox processing of the organic quality leaves. The made organic tea is stored in a separate store room. Once a month the total production is brought to the organisations head office where packaging in 250 g bags is done manually. From here boxes are taken to Colombo and shipped to Europe. In 1998 farmers were paid once a month. The price for 1kg green leaf was little higher than that of conventional leaf with a premium of 7 SL Rs per kg paid once a year. Since 1992 Helvetas[5], a swiss society for international co-operation is giving financial support and technical advice to GSS. About 29 % (1750 kg Broken Orange Pekoe BOP) of the TSH production in 1998 was sold through Helvetas in Switzerland and Germany. A third (1940 kg Tea Dust) was sold locally as organic but for a regular local price. Main consumers are the organic TSHs themselves, a consumer group in Kandy regularly supplied with organic vegetables through GSS and foreigners visiting GSS or the Nillambe Meditation Centre in the vicinity of the farm.

The other group of organic farmers selling their leaf to Bio Foods Ltd. are paid a set premium price for the delivered green leaf (30 SL Rs per kg in 1998), which is more than 50 % higher than the price paid for conventional green leaf. Payment is done directly every week, after weighing the leaf at the collection points. Bulk tea is sold to contract companies overseas for packing and blending.

5.3.7 Yield comparison

A compilation of yield levels from organic and conventional tea producing systems (Fig. 8) shows a high variation in average yield levels between locations and production systems. Location specific lower yield levels of Udapalatha Secretarial Division as part of the mid country region are reflected and variations caused by intensity of production.

[5] Helvetas, Schweizer Gesellschaft für internationale Zusammenarbeit, CH-8042 Zürich

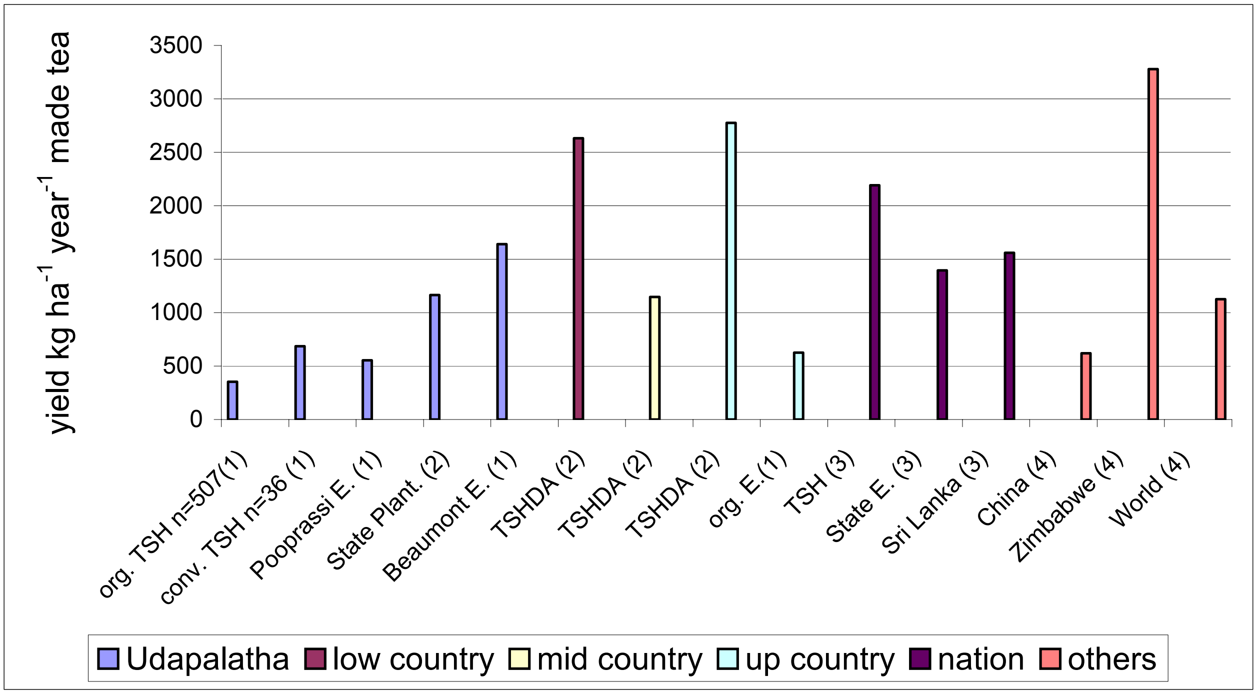

Fig. 8 Compilation of regional yield data from organic and conventional production systems (Tea Small Holder (TSH) versus Estates (E.) / Plantation (Plant.)) of *Camellia sinensis* in Sri Lanka in comparison to others. (1) own data, 1998; (2) TSHDA, 1997; (3) CBS, 1998 a; (4) Tea Board India, 2002.

5.3.8 Economic position and productivity

It is a complex undertaking to give an indication about the economic position of the tea smallholders. Most of them grow other crops like betel nuts, cloves, pepper, coconuts, mango and avocado besides tea on the same area. These crops are partly used for home consumption and barter economy and partly sold as cash crops. If tea and other crops are grown on family land with the help of family labour, income distribution is less comprehensible. Further most households are engaged in various off-farm activities and there is no habit of data recording.

Of the investigated organic tea smallholders in Udapalatha Secretarial Division the average organic yield in a mixed stand came up to 1,432 kg ha^{-1} year^{-1} green leaf (Standard Deviation SD 1,080), in comparison to the average mid country yield level of 4,585 kg ha^{-1} year^{-1} green leaf in a pure stand reached by 25 % of the conventional tea smallholders (Sri Lanka Tea Board, 1996). Productivity of the two organic groups (Bio Foods, Gami Seva Sevana) rose by 16% for tea between 1998 and 2000. Fig. 9 shows improved monthly green leaf yield levels of a group of 91 tea smallholders over a period of 32 month.

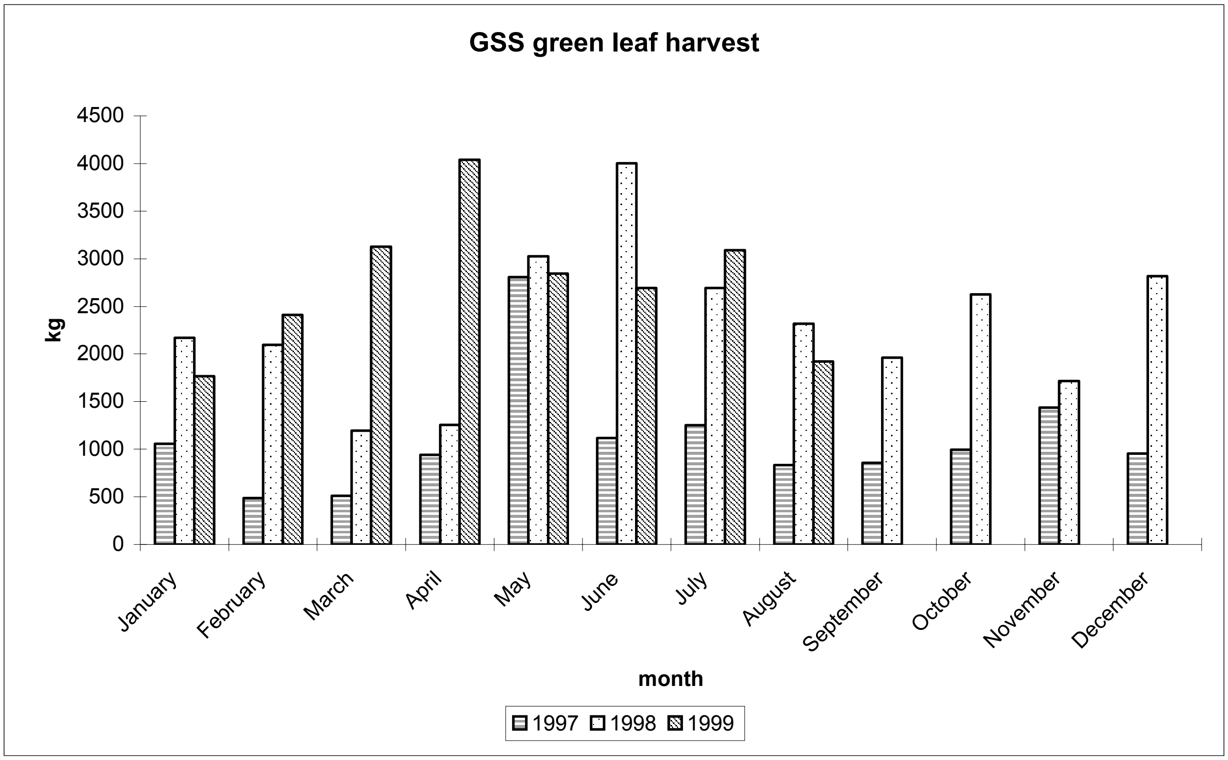

Fig. 9 Monthly green leaf harvest from a group of 91 organic tea smallholders cultivating a total area of 43 ha (mixed cropping) between 1997 and 1999 in Kandy District, Sri Lanka

Green leaf yield of 23 organic TSHs showed an average yield of 365 g per plant (Fig. 10). High variations between farms can be explained by type of propagation (seedling or clone), tea variety, plant density, age of the plants, year after pruning and cultivation techniques. In Southern Tanzania Kigalu (2004) recorded yields of 910 and 340 g per plant green leaf for the clone K35 under different tea plant densities. Taking average conventional green leaf yield of 4,585 kg ha^{-1} (TSHDA, 1997) from a recommended tea stand of 12,800 plants ha^{-1} (TRI, 1995) results into a green leaf yield of 358 g per plant.

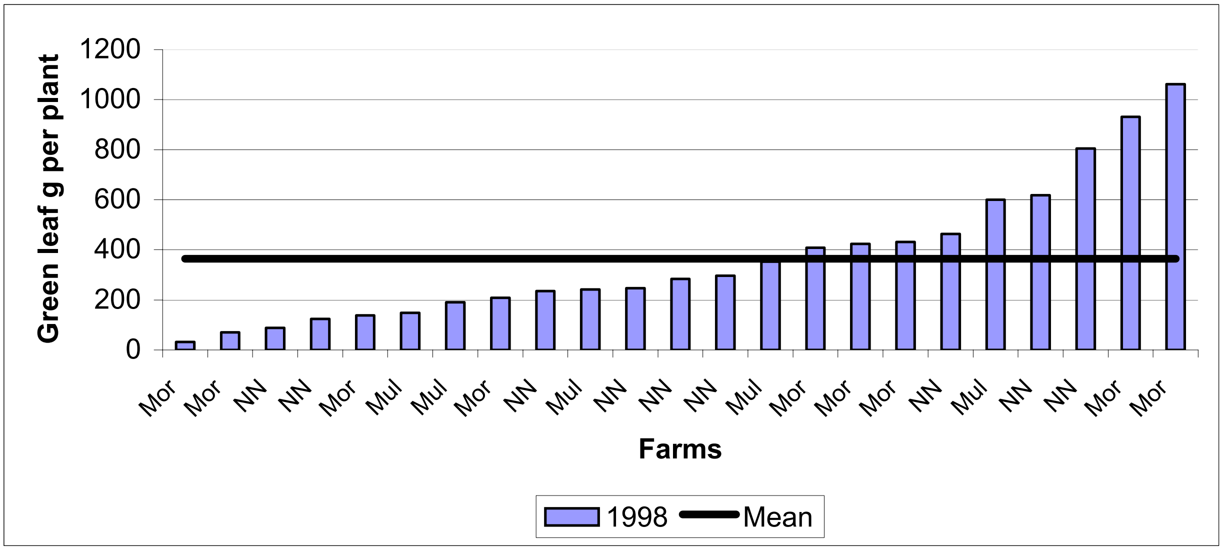

Fig. 10 Average green leaf yield of *Camellia sinensis* in g per plant at 23 organic tea smallholder sites located in three different villages (Mor = Morahena, NN = Nava Nillambe, Mul = Mulgama) of Kandy District, Sri Lanka.

Organic farmers are paid a premium price for their green tea leaf, which is not subject to fluctuations caused by the Colombo auction. Both organisations investigated paid a set price (GSS: 27 SL Rs; Biofoods: 30 SL Rs) as a flat rate in 1998 (respectively 30,-; 35,- SL Rs in 1999), compared to an average conventional green leaf price of 18 SL Rs in 1998. Average income of 507 TSHs from tea production in 1998 was 17,268 SL Rs (267,- US$). Through market access about 64% of the investigated farmers earned up to 1,500 SL Rs per month from organic tea cultivation (Fig. 11).

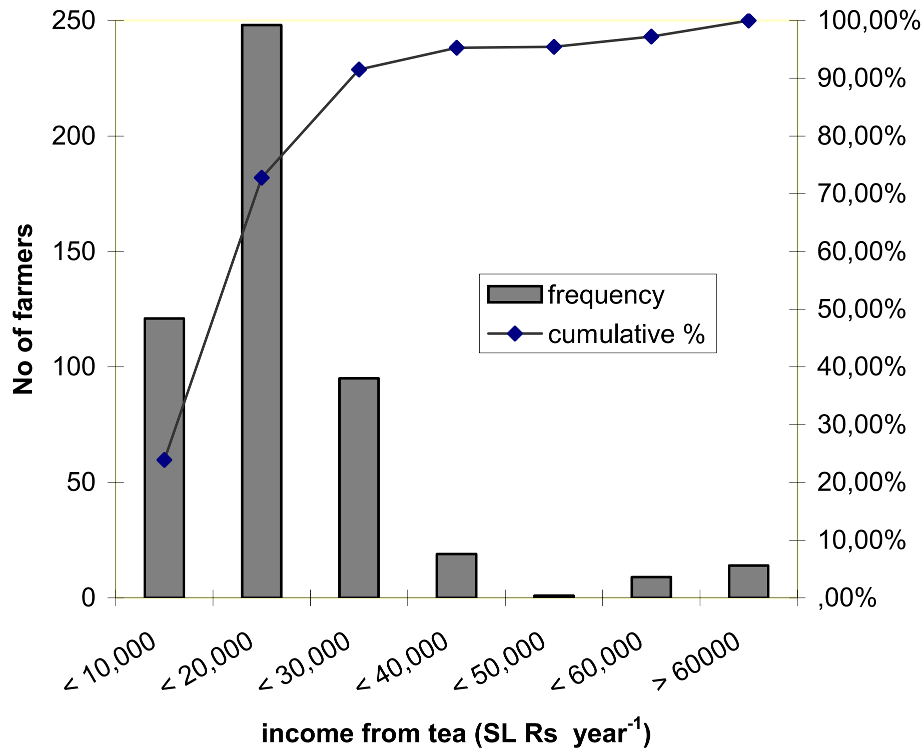

Fig. 11 Annual income from organic tea cultivation of 507 tea smallholders in Udapalatha, Kandy District, Sri Lanka, 1998

Through a comprehensive survey of farm inventory from 23 organic TSH sites in 1998 additional income sources were estimated by recording the number and value of other crops available (Tab. 6). Total estimated farm income from plant production ranged between 1,060 – 55,636 SL Rs year^{-1}. Dominant "cash" crops next to tea were treacle extracted from the fishtail palm (*Caryota urens*), called kitul in Sri Lanka, betelnuts (*Areca catechu*), coffee (*Coffea arabica*), cloves (*Syzygium aromaticum*) and pepper (*Piper nigrum*) (Tab. 8, Fig. 12).

Since less than 40 % of the organic TSHs were involved in animal production, animals are not sold on a regular basis and prices vary according to the season, kind and size the income factor from animal production was not considered. Only milk yield was estimated. Similar, income from timber tree growing was considered with a symbolic price of 1 SL Rs per unit due to high price differences according to type, age and quality of the wood and irregular selling times.

Tab. 8 Summary of agricultural income sources in Sri Lankan Rupees (SL Rs) of organic tea smallholders in Udapalatha, Kandy District, Sri Lanka for the year 1998 (74,- SL Rs equal 1,- € in 1998)

	Income		
Source	Mean	Median	SD
Tea[1]	17268	14400	13153
Fruits[2]	5208	5594	2948
Nuts[2]	2382	690	3822
Treacle[2]	2476	1600	2552
Spices[2]	4532	4190	4865
Coffee/ cocoa[2]	1667	680	2527
Others[2]	149	85	292
Milk[3]	7560		
Sum	41242		

[1]mean of 507 TSH; [2] mean of 23 TSH; [3] estimate

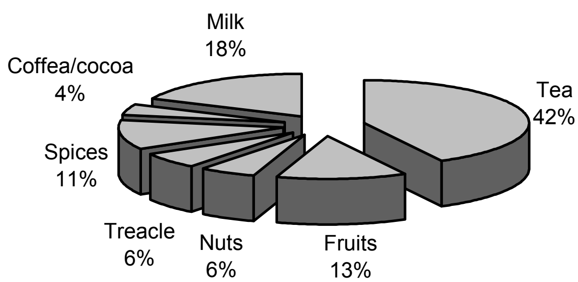

Fig. 12 Percentage share of different crops on the agricultural income of organic tea smallholders in Udapalatha, Kandy District of Sri Lanka (1998)

In a household survey by the Department of Census and Statistics average annual household income[6] was investigated as 78,948 SL Rs[7] in 1995/96 with large differences among the urban,

[6] household size 4.5 persons, No. of income receivers 1.8 (Department of Census and Statistics, 2002 c)

[7] equals 1,222,- US\$ year^{-1}

rural and estate sector. On national level the average annual income from tea of 17,268 SL Rs is still ranking on a comparatively low level. Adding the income created from other crops including animal husbandry, annual income from organic farming (41,242 SL Rs in 1998) almost meets the average income of 46,452 SL Rs as given for the estate sector (Department of Census & Statistics, 2002 c). Because of income generation saving schemes have been introduced and have helped farmers to realise individual projects like establishment of nurseries, building of stables and biogas plants, as well as buying of tools and animals. Since off farm income was not considered in this survey and subsistence production cuts down food expenditures, potential farm income can be considered as a predictable financial platform to be topped with non agricultural activities like weaving or outside employment. Remembering farmer's initial situation of subsistence, market access has brought financial liquidity and buying power.

5.4 Discussion

In 1998 the organic tea project was in a developmental stage meaning that through market access already available resources were used for income generation. In their present role farmers were in charge of a complex cultivation system under favourable natural conditions mainly influenced and structured through the history of the land and the personality of the farmer. Since the standards of agricultural performance have been low for the majority of organic TSHs there was a high potential for improvements on the production level. Access to knowledge about organic farming was a precondition for further development since financial resources were not available. Here the respective organisations were strongly engaged and have provided dedicated extension service. Project intention was to further raise agricultural output by improving farmers' skills and intensifying the diverse cultivation system. Assessment of farm inventory has been an effective tool identifying additional income sources. On site study allows the following recommendations:

When focusing on organic tea as the main cash crop, the tea stand has to be further improved by filling vacancies and replanting unproductive tea plants. Both organisations have established their own nurseries to raise organic saplings. Next to VP clones, selection and cultivation of seedling tea bushes is important to consider when cultivating steep slopes and in regions with extended drought periods or following organic cultivation principles. Only seedling tea bushes develop a deep tap root, withstanding adverse soil and climatic conditions (TRI, 1986).

Regarding tea quality there are only two internationally popular local brands of "Ceylon" tea available. About 59% of the total export volume during 1998 was bulk tea, which is mainly used for blending uniform qualities (CBS, 1998 a). Specific regional and seasonal flavours are lost and international tea companies earn a large share of the value addition through packaging and marketing. This situation creates a chance to serve the market with high quality organic tea of characteristic flavour. Seed tea populations are extremely heterogeneous. The heterogeneity comprises a greater variety or special character of the tea quality, which tea specialists see as lost due to large uniform clonal tea areas.

Necessary rehabilitation periods should be of economical value for the farmer by cultivating e.g. mana grass (*Cymbopogon nardus*) in combination with maize (*Zea mays*) as a cash crop. If sufficient quantities of organic manure (12 t ha^{-1}) are available young tea can be planted without former rehabilitation and intercropped with cowpea (*Vigna unguiculata*) or soybeans (*Glycine max*) during the establishment period. Recommendations by the TSHDA to replace an "unproductive" rehabilitation period with guatemala grass (*Tripsacum laxum*) e.g. by planting infillings with 1 kg compost was hardly accepted by conventional farmers, because they are not used to making and using compost (Someratne, 1999 pers. com.). Experiments by Wadasinghe (1998) focused on the post-replanting rehabilitation effects of mana grass, wild sunflower (*Tithonia diversifolia*), *Gliricidia maculata* and *Flemingia congesta* on tea, resulted in a reduced degree of drought effects, good plant establishment and financial advantages of plucking two years earlier.

Production should partly aim more strongly at domestic markets, which offer the opportunity to add value through processing rather than exporting commodities. Egypt e.g. grows a wide variety of organic crops (fruit, vegetables, cereals, spices, tea, cotton, medicinal plants) on more than 2,500 ha of land. Today 80 % of its produce is sold within Egypt and other parts of the Arab world. Further there is evidence of growing domestic markets for organic produce in China, India, Japan, Sri Lanka and the Philippines (Parrott and Marsden, 2002). In Sri Lanka marketing of organic tea provided the infrastructure, contacts and financial platform for the marketing of other products. In 1999 smallholders' organic tea, coffee and spices were offered at a local supermarket in Kandy marked as organic and sold for a regular price. Small quantities of fruit and vegetables were sold through an organic vegetable co-operative serving a consumers group in Kandy. Negotiations with canning factories interested in organic fruit for juice concentrate production and spices for gherkins have taken place. Further the Ayurvedic Society is a potential buyer of organic herbs and medicinal plants for their preparations.

A study by Kumar (1998) brings out the joint and independent roles of women and men in the conservation of terrestrial and marine biodiversity in Sri Lanka. During the last century gender roles have changed (Wickramasinghe, 1994) and the growing commercialisation in agriculture is leading to marginalisation of women in the intellectual aspects of biodiversity management. Women's' knowledge in identifying improved genetic material, seed saving, food processing and storage, harnessing non-wood forest products and identifying and cultivating medicinal plants is deteriorating. Further marketing of cash crops is done by men, keeping financial control. To consider gender aspects in biodiversity management in the organic context can place men and women into new appropriate roles.

5.5 Conclusion

Rural poor people tend to share the characteristics, besides being poor, also being isolated, physically weak, vulnerable and powerless. Survival is a constant preoccupation, most basic survival means food and not being ill or injured (Chambers, 1983). Resource poor farmers in the mid country of Sri Lanka have realized that their economic survival as farmers will be maintained by adopting environmentally sound techniques and products. Contemplation of traditional cultivation techniques combined with modern scientific ecosystem knowledge supports a diverse and highly productive cultivation system without dependency on expensive external inputs. Acting as a uniform and reliable group under the infrastructure of an organisation was a precondition for successful development of the investigated farmers. Through continuous knowledge transfer, contract farming and premium prices paid a predictable income is provided. Here the formation of private saving groups and loan schemes has helped to realise individual projects, so that resource poor farmers are given the responsibility and chance to improve their standard of living by improving their cultivation system. Some investigated farmers decided to stop their outside employment after concentrating on the organic cultivation system, generating the same income but saving travel expenditures. Next to economic security gained, organic agriculture practices prevent soil erosion and water pollution, increase biodiversity and improve the protection of the environment for future generations in a country with high population density and low standards of living for the majority of people. Here once again, food security is not so much a question of production than of distribution, market access and money supply (Chambers, 1983).

6 Production details of organic tea estates in Sri Lanka

6.1 Introduction

In 1998 six estates grew certified organic tea on an area of 1,140 hectares mainly situated in Badulla District, Uva Province. Some estates like Needwood are privately owned, others belong to larger companies like Lanka Organics Ltd., Maskeliya Plantations Ltd. or Stassen Natural Food Ltd. Detailed information about production is available because of the traditional comprehensive way of book keeping introduced by the British. All organic estates have been converted from conventional cultivation practices through at least a two year period of conversion. On about 80 % of the area predominantly seedling tea is growing (older than 50 years) with vegetative propagated (VP) infillings. The Stassen project is following the bio-dynamic principles as taught by Rudolph Steiner. In December 2000 altogether ten tea gardens had converted to organic production in Sri Lanka covering an area of 1,300 ha with a total production of approximately 800 t made tea (FiBL, 2002).

6.2 Plant production

The organic estates are characterized by larger units, so called divisions, of 2-88 hectares in size. All estates have a comparatively higher bush density of 60-95 % than the investigated smallholders. Strong initiatives were taken to fill vacant patches with clonal tea varieties. Plantation crops like tea are grown in monoculture. However a certain degree of diversification was aimed for in organic cultivation. Trees were integrated in the system for shading, supplying mulch material, as borders or windbreaks and with a plant protection potential (*Azadirachta indica*). Sometimes pepper (*Piper nigrum*) was cultivated on shade trees (mainly *Gliricidia sepium*) in tea areas and coffee (*Coffea arabica*) between the tea bushes as a mixed stand. Next to tea most estates had separate areas for growing fuel wood and timber trees, as conservation forest land, diversification land, thatch bank, for coconut and banana cultivation as well as growing of citronella (*Cymbopogon nardus*), vetiver (*Vetiveria zizanioides*) and lemon grass (*Cymbopogon citratus*) for the production of essential oils.

6.3 Animal production

There is no tradition of rearing animals at the estate level. Next to plant residues animal manure was used to foster a quick decomposition process and a better quality of the compost material. To assure a sufficient supply of animal manure some estates have established a cowherd for dairy farming consisting of up to 24 milking cows. The rearing of animals has to be in line with the international organic standards following certain obligations regarding the type of fodder, stable set up and walking areas as well as sanitation and medication. This is not easy to realise in an estate environment. There was a positive effect of creating additional employment and selling milk generates income. But there was no demand for “organic” milk and as a whole animal production can be more of a burden for the management. Other estates bought animal dung from neighbouring smallholders or supported estate labourers rear animals.

6.4 Manuring

6.4.1 Composting

All estates were heavily involved in the process of making compost. There are various methods and materials used. Main materials used were plant residues, animal manure, minerals and additives. Plant residues consist of weeds (herbs), grasses and cuttings from trees and hedges. The plant residues were gathered within the tea garden, along the borders, pathways and roads. Some estates imported additional plant material mainly consisting of grasses from “no-mans-land” at a rate of 5 tons per month or from thatch banks and uncultivated areas belonging to the estate. Branches and bulky materials were chopped or shredded before incorporated into the heaps. One project was buying made compost from a compost project by Sidhalepa in Anuradhapura at a rate of SL Rs. 4.5 kg^{-1} (inclusive transport to the estate) since cost of compost production at the estate came up to SL Rs. 8,- kg^{-1}. Further dolomite, factory ash, rock phosphate and biodynamic compost preparations were used. In the initial state chicken manure from intensive conventional broiler production was bought and incorporated into the compost heaps.

Compost was mainly prepared in heaps located throughout the garden or at special composting sites (Fig. 13). Plant residues, farmyard manure, dolomite or factory ash (50 kg per layer) and rock phosphate were placed in repeating layers. The final manageable dimension of the heap was around 7.5 m long, 2 m broad and 1.2 m in height. The heap was turned twice after 4-6 weeks. Within 3-4 months compost was ready for application. One cubic meter of fresh compost weighs 420 kg, resulting in 7.5 tonnes of compost (3.8 tons air dried matter) from one heap. The entire plantation was given a basal application of compost at the rate of 3 kg per bush in the year of prune. Approximate costs including transport for the production of 1 ton were 40 US $ in 1998.

Fig. 13 Composting side

6.4.2 Trench composting

For the maintenance of a convenient height for easy harvesting, the stimulation of vegetative shoot growth, the maintenance of a healthy frame and stabilisation of the crop, tea bushes are deep pruned about every four years. Pruning removes substantial amounts of leaves and branches. In general pruning litter is removed from the tea fields by the workers and used as firewood for cooking. Investigations mentioned by Barua (1989) estimated nutrient losses of 785 kg ha^{-1} nitrogen, 135 kg ha^{-1} phosphate and 570 kg ha^{-1} potassium (K_2O) in 22,400 kg of pruning litter over a period of 3 years. Some organic estates have adopted a method of “in situ composting” by burying the pruning litter along with other organic material, compost and farmyard manure in trenches (45cm wide, 25cm deep) between alternate tea rows at the time of deep pruning (Kohlwes, 1995). This has been proven effectively and further described by Howard (1979) and Bannerjee (1991).

6.4.3 Mulching

With the ongoing problem of soil erosion on slopes cultivated with tea the organic planters realised to stop clean weeding and forking for aeration. The aim is to keep the soil covered, to get the feeling of “walking on a thick spongy mattress as in the well grown forest land” (Bannerjee, 1997). In order to provide a continuous supply of green manure various methods were adopted.

Entire estates like Needwood were planted with green manure trees like *Gliricidia sepium* and *Erythrina orientalis* for low shade. Within a period of two years a stand of about 1850 trees per hectare of high and low trees was established. Trees can serve as shade, border, hedge and windbreak. Regularly lopping of two to three times a year can generate 50 kg of green mulch per tree each year yielding a total biomass of 92.5 t ha^{-1} (Modder, 1997). The permanent soil cover has had an important bearing on the hydrology of the surrounding, maintaining a water level during the drought season. Further it was observed at several sites that mulched organic tea plants suffer less drought symptoms than neighbouring conventional tea plants (Bannerjee pers. communication, 1997; Kohlwes, 1995; Modder, 1997). At Makaibari estate in Darjeeling, India, guatemala grass (*Tripsacum laxum*) was planted in vacant patches throughout the tea garden in the initial stage. Within two years it was well established and lopped and mulched 2-3 times per year. But with an improved tea stand available areas for guatemala grass decreased. Special land was reserved for the growing of guatemala grass at the rate of 1 acre guatemala for 10 acres of tea (Bannerjee, 1997). Further zig-zag mulching was adopted where plant material was placed in such a way that the tip of the plant material was directed towards the slope in one layer, covered with a layer of plant material placed perpendicularly. This provides optimum living conditions for soil micro and macro flora, improves soil and moisture conservation, suppresses weed growth and degrades slowly adding organic matter to the soil. Intentional *in situ* vermi composting was initiated in these areas by placing fermenting materials to attract earthworms or by releasing earthworm populations raised in vermicompost into the field. Some estates have planted *Vetiveria zizanioides*, which establishes a large fibrous root system, on the contours and along side the path as soil conservation measures regularly chopping and mulching the growing material. Koslanda estate was growing hedge rows of wild sunflower (*Tithonia diversifolia*) as a buffer zone and wind break in the tea field and for continuous supply of mulch material. Vacancies were planted with crotolaria, *Vetiveria zizanioides*, mana grass (*Cymbopogon nardus*) and wild sunflower to prevent excessive weed growth, soil erosion and to provide mulch material. Bulky material like pruning litter and shade tree branches were chopped or shredded before distribution.

6.4.4 Oil cakes

Further various types of oil cakes were distributed among the tea plants in order to improve the organic matter and nutrient status of the soil (Tab. 9). Depending on the location and time of application the oil cakes were forked into the soil or buried in trenches with the remaining pruning material every 4-6 years. Some fields were supplemented with the addition of oil cakes at the rate of 3,000 kg ha^{-1} $year^{-1}$.

Tab. 9 Nutrient content of oil cakes used as organic fertilizer in tea estates, Sri Lanka 1998 (own data)

Oil cake	Botanical name	Nitrogen %	Phosphorus %	Potassium %
Rubber seed	*Hevea brasiliensis*	1.5 – 2.0	0.25	1.0
Neem	*Azadirachta indica*	1.4 – 3.6	0.34	1.6
Ground nut	*Arachis hypogaea*	3.6 – 4.8	0.30	1.3
Kapok	*Ceiba pentandra*	3.8	0.28	1.5
Copra extraction	*Cocos nucifera*	1.5	0.16	0.6

6.5 Extracts for plant protection and growth enhancement

Extracts from *Adathoda vessica* (1kg chopped leaf soaked in 3 litres water for 12 hours, sieved and diluted with 3 litres water) were effectively used against aphids (*Toxoptera aurantii*) on young tea plants and in vegetable cultivation. Mite attack (*Oligonychus coffeae*) was sprayed with ashes of *Lantana camara* trees. Insect attacks and shot hole borer (*Xyleborus fornicatus*) were sprayed with a neem seed powder solution. Further caffeine was found to inhibit oviposition and delay the appearance of different developmental stages of the shot hole borer (Hewavitharanage et al., 1999). Termite mounts and ant hills are watered with a solution of 2 kg wild sunflower leaves (*Tithonia diversifolia*) and 2 kg *Cassia auriculata* leaves soaked in 10 litre water (Koslanda). Besides the pests mentioned above blister blight, caused by the fungus *Exobasidium vexans*, is the only disease of economic importance in Sri Lanka first recorded in 1946. Organic farmers were allowed to spray a copper solution until 1999 afterwards using a wood ash formula.

Water passing slowly through a vermiculture unit (Hu et al., 2003), collected at the bottom is referred to as vermiwash (manufactured by Akshat Farms (2004), Udaipur, Rajasthan, India). Foliar sprays of vermiwash at various concentrations ranging from 1:7 to 1:10 were used to improve plant growth, buffer stress symptoms and strengthen the plant against diseases. Spraying was done in the evening hours and the spraying mixture should moisten the leaf. Foliar sprays prepared out of leaves from *Gliricidia sepium* (3.5 % N in dry leaf) and *Tithonia diversifolia* (4.2 % N in dry leaf) were used as a quick source of nitrogen (De Costa and Atapattu, 2001).

6.6 Weed management

Weeding was done manually in a 3-4 months interval by slashing and mulching and clean weeding of 'hard' weeds like cooch (*Agropyron repens*) and illuk (*Imperata cylindrica*) grass. For weed suppression *Arachis pintoi* was planted as a cover crop. Biological control was done by planting mustard and *Brachiaria brizantha*. For bush sanitation moss and ferns were removed periodically.

6.7 Processing, marketing and infrastructure

All the leaf from organic tea estates was exclusively processed in factories only processing organic leaf of orthodox quality. Broken Orange Pekoe (BOP), Broken Orange Pekoe Fannings (BOPF) and Fannings were the main grades produced. Organic tea was mainly sold through direct contacts with overseas buyers and did not go through brokers and auctions, loosing money to the middle man. Value addition was achieved when tea was not sold in bulk but as tea packets or tea bags and packing was done inside the country. Blending and packing was done through contract factories in Colombo. The final product was directly shipped from Colombo to overseas destinations. Necessary transport facilities were provided by the company or through contract companies.

6.8 Economy and productivity

During the period of transition from conventional to organic cultivation practices yield levels in general showed a decline of 40-60 %. With the continuous supply of organic manure yield levels improved and reached a steady level between 60 % and 80 % of the conventional yield level after a period of 4-6 years.

Yield levels at Needwood estate ranged between 500 and 600 kg made tea per hectare and year. The cost of production were very high compared to other conventional estates, adding up to about 6 US $ per kg in 1997, inclusive of the bulk and value added products. Reasons for the high cost of production (COP) were the low plucker input averaging only 7 kg green leaf per day (as to 20 kg per day at conventional estates), the large volume of field inputs in the form of compost materials, oil cakes, dolomite and green manure (with their cost of application) and the cost of certification. This could be compensated by higher prices fetched for organic tea at the rate of 7.50 US $ kg^{-1} in 1997. In respect of the Uva region, it is seen that estates adjoining Needwood had a COP of about Sri Lankan Rupies 91 kg^{-1} in 1996 and Net Sales Average (NSA) of about SL Rs. 102 kg^{-1}, thereby generating a surplus of Rs. 11 kg^{-1} made tea. With an average yield of 1,200 kg ha^{-1} a^{-1} a surplus of about Rs. 13,200 per hectare could be generated. Despite a lower yield level of 523 kg ha^{-1} and year and COP of about 6 US $ Needwood generated Rs. 42,000 per hectare. In 1996 organic smallholders supplying their leave for processing to organic estates achieved about SL Rs. 35 kg^{-1} green leaf compared to about SL Rs. 15 for those supplying their leaf to conventional factories (Modder, 1997).

6.9 Conclusion

Already in 1987 the first organic tea estates were certified in Sri Lanka and started pioneer work. Two conferences about organic tea in 1991 and 1997 organized under patronage of IFOAM aimed to build a platform for growers and traders to exchange knowledge about organic tea cultivation. Since most estates are part of a larger company, they had a clear advantage of infrastructure provided for the adoption of organic agricultural practices and marketing of organic quality tea. Some estates investigated into new market channels with so called ‘garden teas’, placing the estate name as a brand name. Survey results showed more of a high input system in comparison to the investigated smallholder production. Information available with regards to organic manuring techniques and plant protection measures were partly investigated under supervision of the Tea Research Institute and foreign scientists. Several specific experiments have been carried out in a scientific order and economical details are available.

Part III Field and laboratory investigations

7 Effect of organic amendments on the establishment and growth of *Camellia sinensis*

7.1 Introduction

Tea, *Camellia sinensis* (L.) O. Kuntze, originated in the highlands of south-west China, Myanmar and north-east India. The natural habitat of tea is the undergrowth of subtropical forests. Today tea is being cultivated between 42° N (Russia) and 27° S (Argentina) longitude, at altitudes ranging from 2,200 m asl right down to sea level. Tea is a crop of wide adaptability and grows in a range of climates and soils in various parts of the world. As a stimulant and luxury beverage it gained importance during colonial times and large plantations were established mainly in India, Kenya, Indonesia and Sri Lanka. Until 1875 commercially grown tea in India was hardly fertilized at all. The tea plants were living of the soil reserves from previously cleared forest areas. With increasing demand and decreasing yields planters started to collect organic material in the vicinity of the estate distributing it on the tea fields. This kind of organic fertilization continued until the first world war. After the war ammonium sulphate was given for the first time and research started on the effects of artificial fertilizer on the yield and quality of tea (Barua, 1989). Further Sir Albert Howard (1979) contributed essential improvements with the invention and dissemination of various techniques for the production and application of compost in tea. He pointed out the role of humus for the development of mycorrhiza on the tea roots as a healthy and more productive symbiosis. Today commercial tea growing is mainly a high input agricultural enterprise with regards to agro-chemicals and processing technologies. But with growing environmental, social and health consciousness organic agriculture practices have become a widely accepted alternative. Since most of the tea growing organic now was raised under conventional circumstances in the nursery and field, there is a demand for organically raised tea plants in order to do infillings, replanting or even new planting on existing organic sites. So far the application of compost, various mulch materials and oil cakes has been an important cultural practice for fertilization, soil conservation and plant protection in tea lands (Howard, 1979; Wijeratne et al., 1994; Prematilaka et al., 1998; Mohotti, 1998). Organic tea estates in Sri Lanka and India manage to apply 37-61 t compost dry matter (DM) ha^{-1} every four years. However this practice is often restricted due to unavailability of recommended materials in adequate quantities. During the research period the dissemination of biogas plants and the use of bioslurry from these biogas plants to maintain and improve soil fertility were promoted in the project area. Due to its plant nutrient content and humus forming effect, bioslurry has traditionally been highly regarded as a valuable fertilizing material. Fertilizer processing and energy production are the two main reasons for operating a biogas plant. However Gutterer & Sasse (1993) concluded in a comprehensive biogas survey that 90% of the investigated 109 farmers from 14 countries gave main priority to the production and use of biogas. The use of bioslurry as liquid manure and its intensity is highly dependent on the fertilizing tradition, individual interests, location and exposition of the fields, transport facilities and the quality of extension service. Positive impacts on soil fertility and plant growth enhancement after the application of bioslurry in the tropics have been reported by Hinterberger (1990) regarding vegetables, Tiwari et al. (1997) for sugarcane and Ojha & Talukdar (2000) for rice. Application of bioslurry showed better response on sugarcane growth at Sehore, India, which may be attributed to better dispersion and reversible flocculation of the colloidal matter of slurry (Tiwari et al., 1997). Ojha & Talukdar (2000) mentioned that the favourable effect of biogas slurry on yield and yield parameters of direct seeded rainfed rice (*Oryza sativa*) in Assam, India could be attributed to early decomposition and mineralization leading to efficient utilization of nutrients. A study by Chen, 1997 showed how a biogas plant served as a key link between fruit farming (*Citrus grandis*) and animal husbandry alleviating the scarcity of rural energy. From literature survey no information could be gathered regarding the feasibility of using bioslurry as an organic amendment in tea.

Hence, this part of the study aimed to investigate the effects of bioslurry in comparison with two locally available composts on the establishment and growth of young tea. Investigations were carried out under field conditions by recording various growth parameters and analysis of soil and manure samples. The field research was carried out in co-operation with the Tea Research Institute of Sri Lanka (TRI), Talawakele and the small farmers co-operative Gami Seva Sevana (GSS), Galaha.

7.2 Material and methods

7.2.1 Location and climate

The field trial was conducted from June 1998 to October 1999 at the demonstration farm of the small farmers co-operative Gami Seva Sevana (GSS) located in the mid-country of Sri Lanka, Kandy District, Secretarial Division (DS) Udapalatha. The experimental site was located 18 km south of Kandy (Nava Nillambe) at an altitude of 750 m above sea level. It belongs to the agro climatical wet zone "wm2" (Department of Agriculture, 1981) experiencing two rainy seasons with an average precipitation of 2,200 mm yr^{-1} and annual average temperature of 24 °C. The soil is a reddish brown Ultisol belonging to the great group Rhododults, covering approximately 80 % of the Sri Lankan land mass (Peiris, 1977; Panabokke, 1996), locally known as Red Yellow Podzolic. The region is characterized by a mix of plantation management, peasant farmers and Kandyan forest gardens.

7.2.2 Set up of field experiment for plant establishment and growth evaluation

In May 1998 a trial field was established on a terraced slope (5 – 8 %) by the garden of the small farmers co-operative GSS. For more than 3 years no pesticides and artificial fertilizer were used

in and around the field. The area was divided into nine plots of 28 m^2 (5 m x 5.6 m). Planting holes of conal shape 45 cm deep with an open diameter of 30 cm at the surface level were dug. In each plot 5 rows with 7 tea plants were accommodated at a planting distance of 60 cm in the row and 120 cm between the rows according to a square planting pattern. The plots were arranged in two parallel strips separated and surrounded by a 1.5 m broad and 2-5 m tall hedge planted in 1991, mainly consisting of plants with pest control properties like *Justicia adhatoda* and *Vitex negundo*. Conventionally raised tea plants (12 months old) of the clone T 2025 were purchased from TRI Hantana and planted on June 20th 1998 using three types of locally available organic amendments. It was determined to use three treatments namely goat compost (GC), bokashi (BK) and bioslurry (BS) at a rate of 5 kg / 5 kg / 5 kg fresh material per planting hole. The experiment was arranged in a randomised complete block (RCB) design with three replications.
Goat compost was made out of goat manure and the remaining materials from the roughage feed given to the goats. The material was collected daily in compost baskets, 1 m in diameter and 1.5 m height, made out of sticks. Baskets were covered with broad leaves and rested for decomposition for about 3 months. Bokashi is a special fermented fertilizer made according to a Japanese recipe (Ahmed, 1995) using soil (50 %), chicken manure (30 %), pressed rape seed oil cake (15 %), rice bran (2-3 %), charcoal (1 %) and boiled livestock bone (about 1 %). The original recipe was adapted to local conditions replacing rape seed oil cake by neem seed oil cake and livestock bones by dolomite and rock phosphate. All ingredients were well mixed and water added at a rate of 50 % of the material weight. After about three days the temperature in the mixture reached 60-65 °C and for about 10-14 days it was turned (with additional water if necessary) every day to prevent volatile N losses. Within 21 days bokashi was ready to use. Cow and pig excreta passing through a biogas plant, undergoing an anaerobe digestion process for about 70 days are referred to as bioslurry. Goat compost and bokashi were mixed with soil. The bioslurry was poured to the soil while filling the planting hole in order to assure even distribution. The planting holes were filled in a loose manner 2-5 days prior to planting to allow deposition of the soil-manure mixtures. Tea planting was done with the onset of the rainy season in June 1998. During the drought season from February until April 1999 the plots were irrigated to avoid drought stress. Nursery bags were gently removed from the tea plants to avoid root damage. A hollow was formed in the centre of the planting hole and the tea plant was placed inside. The planting hole was topped with soil and tightly pressed onto the root bag until level with the soil surface, leaving the collar of the plant above soil level. Two pegs were put crosswise to stabilise each plant. Shade was provided by the surrounding hedge and controlled by thinning out and cutting back of branches. Immediately after planting the nine plots were uniformly mulched about 15 cm away from the collar of the plant with chopped mana grass (*Cymbopogon nardus*) at a rate of 35 t ha^{-1} fresh material. Mana grass was available from mountain grasslands, so called native patana grassland, where it appears to be a fire sub climax that has developed after the clearing of jungle vegetation. It grows to a height of about 1.2 m and only the tender shoots are eaten by animals. It occurs in almost pure stands at the forest margins and in depressions

(Skerman & Riveros, 1990). After mulching only spot weeding by hand picking especially directly around the plants was necessary. Weeds were removed from the plots to avoid reestablishment of “hard weeds” like *Mikania micrantha*. Manuring was repeated after 3.5 months (Oct. 1998) at the rate of 3 kg of the respective manure per plant. The goat compost and bokashi was incorporated in 25 cm deep trenches cut along both sides at a distance of 15 cm to the tea rows. The bioslurry was poured into forking holes in 15 cm distance alongside the tea rows. On April 13th 1999 the plants were cut across at about 23 cm (9 inches) above the soil.

7.2.3 Chemical analysis and nutrient determination of soil, manure and mulch samples

To evaluate the initial chemical properties of the soil, bulked soil samples (5 single cores) were taken from each plot with an auger (2 cm diameter) to a depth of 30 cm (0-15 cm top soil, 15-30 cm sub soil) prior to crop planting. Soil sampling was repeated as above in January 1999 to evaluate changes in the chemical composition of the soil. Standards given by Pagel et al. (1982), Scheffer & Schachtschabel (2002) and TRI (1995) were used for characterization and comparison of the described soil parameters. At the time of manuring (June 1998) fresh manure samples and an air dried sample of mana grass were taken. The elemental composition of all the samples was determined by standard methods of analysis at the TRI Talawakele and Galle laboratories.

7.2.4 Impact through mulching of *Cymbopogon nardus*

Mulching is an important cultural practice for soil moisture conservation, soil temperature regulation and weed suppression. Newly planted tea fields and pruned sections are especially subject to erosion, evaporation and proliferation of weed growth until a leaf canopy is formed which provides adequate soil coverage. Various studies quoted by Müller-Sämann 1986 and Wijeratne et al. 1994 proved the beneficial effects of mulching. Therefore soil at the research site was mulched with 35 t ha^{-1} fresh mana grass which lies in the required range of 30–40 t ha^{-1} for tea given by Wijeratne et al. 1994. Suppression of weed growth was clearly demonstrated by goat compost plots where profuse weed growth was only observed within the rows close to the tea plants where a 15 cm circle was kept without mulch to prevent overheating of the plant basis. Observed weed growth was highest for goat compost plots and lowest for bioslurry because of different seed content of the organic amendments. Decomposition and nutrient release was neglected in the analytical results of this trial (Tab. 10).

Tab. 10 Nutrient composition of mana grass (*Cymbopogon nardus)* from the mid country of Sri Lanka

	Moisture	Dry matter (%)					C:N	Dry matter (ppm)		
	(%)	N	P	K	Mg	C_{org}	ratio	Zn	Cu	Mn
Mana grass	28	1.36	0.33	1.32	0.45	43	31	50	8	200

Source: TRI analysis 1998

7.2.5 Chemical composition and application rates of organic manure

The chemical composition reflects the nature of the wastes from which the manure was prepared. Analytical results of various compost samples given by Müller-Sämann (1986) and FAO (1987) indicate wide ranges in the chemical composition of matured composts. Analytical results of elemental composition from the compost material used in the trial verify this (Tab. 11). Goat compost showed a fairly high N, P and K content and a narrow C/N ratio. Unexpected low nutrient contents were analysed in the bokashi sample (2 % N e.g. are mentioned by Ahmed 1995). The investigated nutrient content of bioslurry is similar to analytical results reported by Stoer (1995) within the context of a Small Holder Dairy Development Project in the mid country of Sri Lanka. The estimated nutrient application from dried bioslurry neglects the amount of ammonium and potassium ions in fresh bioslurry that get lost through the process of drying. Ranges of seven bioslurry samples analysed by Stoer (1995) showed nutrient contents of 1000-5000 K^+ mg kg^{-1} and 600-3000 mg kg^{-1} for NH_4^+ in fresh matter, which have to be taken into account.

Tab. 11 Composition of organic amendments from the mid country of Sri Lanka, 1998

Organic amendments	Moisture (%)	Dry matter (%) N	P	K	Mg	C_{org}	C:N ratio	Dry matter (ppm) Zn	Cu	Mn
Goat compost	51	1.58	0.45	0.83	0.76	13.5	9	145	56	588
Bokashi	36	0.78	0.05	0.46	0.17	5.5	7	16	19	140
Bioslurry	97	1.72	0.40	0.35	0.25	30.5	18	138	68	437

Source: TRI analysis 1998

To guarantee fertilizing effects the rates of application (Tab. 12) were determined considering the local availability of the material, the expected nutrient content and conventional application rates of T 200 recommended fertilizer for young tea (124 kg N, 36 kg P, 75 kg K, 21 kg Mg ha^{-1} a^{-1}) suggested by TRI. All calculations were done on the basis that 1 ha accommodates 12,350 plants (TRI, 1986).

Tab. 12 Amount of nutrients applied through organic amendments on young tea fields in 1998 at Udapalatha, Kandy District, Sri Lanka

Treatment	DM t ha^{-1}	DM kg ha^{-1} N	P	K	Mg	FM kg ha^{-1} $NH4^+$	K^+
Goat compost	48.4	764	217	401	367		
Bokashi	63.2	492	31	290	107		
Bioslurry	3.0	50	11	10	7	177	296
Mana Grass	25.2	343	83	332	113		

The total amount of nutrients applied is highest for the goat compost and lowest for the bioslurry treatment. The total amount of nutrients applied with organic amendments is higher than the nutrients applied with conventional application of T 200.

7.2.6 Growth assessment

The growth assessments for plant height, total number of leaves, diameter of the collar and primary side branches were done in June and December 1998 and June 1999. To calculate the average plant height per plot the total plant height of the main stem was measured from the soil surface below the final bud. The total number of leaves per plant was determined by counting every mature open leaf including the fish leaf. The diameter of the collar in mm was measured with a calliper rule at 3.8 cm above the soil surface facing west direction. The total number of primary side branches per plot was determined by counting woody and partly woody stems with one or more leaves branching off the main stem. Further the number of casualties occurring in each plot was recorded monthly. On a weekly basis the number of new shoots per plant was recorded until 16. Dec.1998 and repeated once after the beginning of the rainy season on the 12. Apr.1999. A new shoot was considered when at least one leaf was open and growth visible. The field book notes clearly indicate the situation of each single plant, so that changes in growth could be traced over the course of time to avoid double counting of shoots. Likewise the number of plants with new shoots was recorded on a weekly basis in order to evaluate how many plants with new shoots appeared in a specific plot.

7.2.7 Statistical analysis

To describe the initial soil nutrient status of the trial plots data was subject to analysis of variance (ANOVA) using the general linear model (GLM) procedure of the SAS statistical package (SAS Inst., 2000). For distinguished differentiation of the treatments t Test (LSD) and Duncan’s Multiple Range Test were used. Univariate Procedure was carried out to check whether the data follows normal distribution as defined by Kolmogov-Smirnov. To evaluate changes in the soil nutrient status over the course of time 2 data sets (before and after manuring) were analysed using the Mixed Procedure of SAS with Type 3 Tests of Fixed Effects. Normal distribution was checked by the Univariate Procedure (Tab. 14, Fig. 14).

Shoot growth data (Fig. 19) was subject to analysis of variance using the GLM procedure including repeated measures, further t-Test (LSD) and Duncan’s Multiple Range Test of SAS. Normal distribution was checked by Explorative Data Analysis of SPSS (SPSS Inc., 2000). The possible influence of soil nutrients (P, Zn) on shoot growth of different treatments was checked by analysis of co-variance using SPSS.

Growth assessment data (Tab. 13) was subject to analysis of variance by Unianova Procedure of SPSS statistical package (SPSS Inc., 2000), using Levene-Test to examine homogeneity of variance, Post-Hoc-Tests for pairing comparison between treatments at the same time and Explorative Data Analysis to test if data follows normal distribution. If preconditions (homogenous variation, normal distribution) fail non parametric test by Kruskal-Wallis or the Median Test were carried out (Diehl & Staufenbiel, 2001).

For * marked cases (Tab. 13) analysis of variance and test for normal distribution are based on a limited number of cases, since extreme values due to wrong readings were removed (removal of outliners). All significant differences in the mean values were determined at a significance level of $p \leq 0.05$.

Tab. 13 Statistical details of measured growth parameters of newly planted *Camellia sinensis* over the first year in the field

Time		Jun. 1998					Dec. 1998					Jun. 1999				
Parameter	Treatment	Test	N	Ø	SD	Sig.	Test	N	Ø	SD	Sig.	Test	N	Ø	SD	Sig.
Height	Bioslurry	VA, NV	104	27.76	7.12	n.s.	VA, NV	104	29.68	7.14	n.s.			n.a.		
(cm)	Goat compost		105	28.55	6.78	n.s.		105	30.55	6.87	n.s.			n.a.		
	Bokashi		101	27.12	7.12	n.s.		101	29.08	7.04	n.s.			n.a.		
Diameter	Bioslurry	VA, NV,	83	3.867	0.593	n.s.	VA, NV	37	4.505	0.708	a	VA, NV	86	5.109	0.932	a
(mm)	Goat compsot	K.-W.	79	3.873	0.493	n.s.		34	4.479	0.764	ab		82	4.724	0.789	b
	Bokashi		77	3.861	0.565	n.s.		36	4.294	0.750	b		72	4.868	1.082	ab
Leaves	Bioslurry	VA, NV,	77	10.39	1.95	n.s.	VA*, NV	26	16.654	7.310	a	VA*, NV	83	23.217	10.449	a
(No)	Goat compost	K.-W.	72	10.54	2.01	n.s.	K.-W.	27	12.370	4.765	b		74	17.865	8.023	b
	Bokashi		72	10.60	1.97	n.s.		28	12.500	5.232	b		64	17.781	9.049	b
Branches	Bioslurry	VA, NV,	104	0.81	0.88	n.s.			n.a.			VA, NV	90	3.80	1.62	a
(No)	Goat compost	K.-W.	105	0.98	0.94	n.s.			n.a.				83	3.33	1.67	ab
	Bokashi		101	1.07	1.18	n.s.			n.a.				75	2.81	1.95	b

N: number of observations Ø: average
SD: standard deviation Sig: significant
n.s.: not significant n.a.: not available
a,b,c: means with the same letter are not significantly different $p<0.05$
VA: analysis of variance; *based on a limited number of cases
NV: normal distribution
K.-W.: non parametric test by Kruskal-Wallis

7.3 Results and discussion

7.3.1 Initial soil status and changes through the application of organic amendments

In order to interpret the data regarding plant growth after the application of different organic amendments, uniformity of the initial soil status before commencement of the trial in June 1998 was investigated on the top (0-15 cm) and sub soil (15-30 cm) level. Soil sampling was repeated after 7 months in January 1999 to evaluate changes resulting from plant growth and organic manuring (June and October 1998) (Tab. 14; Fig. 14).

Following the US-soil taxonomy the soil at the research site can be classified as loamy clay (40 % sand, 25 % silt, 35 % clay; De Costa, 2001). At the commencement of the trial the soil was slightly acid. The mean pH of 6.2 in the top soil layer was only little lower than in the sub soil layer (pH of 6.4). The carbon content ranged between 1.9 - 2.75 % in the top soil and 1.1 – 2.1 % in the sub soil layer and can be considered as moderate at this location. Further total nutrient contents showed that especially for nitrogen (N) and potassium (K) the optimum levels for tea cultivation given by TRI (1995) were reached and for phosphorus and magnesia 5 to 7 times higher levels could be found at 0-15 cm. On the sub soil level N and K contents were low and P and Mg contents above the optimum level. The share of the trace elements manganese, copper and zinc was more than sufficient for plant growth (Tab. 14).

Statistical analysis of the soil analytical results was used to evaluate the uniformity of the initial soil status (June 1998) of the nine plots and between the three treatments. For the total P content in the top soil layer significantly different means ($F_T = 0.027$) between the bokashi treatment (106 ppm) on the one hand and the goat compost and bioslurry treatments (131 ppm, 113 ppm) on the other hand were found. Besides there were significant differences in the total P content within the replications ($F_R = 0.013$). On the sub soil level significantly different means ($F_T = 0.017$) for the total Zn content between the bokashi treatment (5.46 ppm) on the one hand and the goat compost and bioslurry treatments (7.9 ppm, 8.6 ppm) on the other hand were found in the analysis. Also there were significant differences in the total Zn content within the replications ($F_R = 0.014$) (Tab. 14).

Tab. 14 Chemical soil characteristics of a trial field at Nava Nillambe, Kandy District, Sri Lanka on top soil (0-15 cm) and sub soil (15-30 cm) level at the initial stage in June 1998 and after manure application (Oct. 1998) in January 1999 (means of 27 mixed soil samples)

Top soil								
Sampling date	Jun. 1998				Jan. 1999			
Significant differences			a	b			a	c
Soil parameters	Mean	SD	Treatment[1]	Replicate[1]	Mean	SD	Treatment[1]	Time[2]
pH ($CaCl_2$)	6.22	0.05	n.s.	n.s.	6.14	0.17	n.s.	n.s.
C org. (%)	2.35	0.25	n.s.	n.s.	2.42	0.19	n.s.	n.s.
N total (%)	0.23	0.02	n.s.	n.s.	0.28	0.03	n.s.	*
P total ppm	116.88	4.87	*	*	492.88	339.58	n.s.	*
K total ppm	135.22	46.37	n.s.	n.s.	100.22	37.26	n.s.	n.s.
Mg total ppm	345.33	45.4	n.s.	n.s.	380.77	84.35	n.s.	n.s.
Mn total ppm	75.22	10.53	n.s.	n.s.				
Cu total ppm	12.50	1.04	n.s.	n.s.				
Zn total ppm	11.63	1.36	n.s.	n.s.				

Sub soil								
Sampling date	Jun. 1998				Jan. 1999			
Significant differences			a	b			a	c
Soil parameters	Mean	SD	Treatment[1]	Replicate[1]	Mean	SD	Treatment[1]	Time[2]
pH ($CaCl_2$)	6.43	0.08	n.s.	n.s.	6.28	0.22	n.s.	n.s.
C org. (%)	1.48	0.24	n.s.	n.s.	1.94	0.34	n.s.	*
N total (%)	0.14	0.01	n.s.	n.s.	0.21	0.04	n.s.	*
P total ppm	86.77	13.13	n.s.	n.s.	519.88	332.86	n.s.	*
K total ppm	75.88	9.18	n.s.	n.s.	94.44	29.71	n.s.	n.s.
Mg total ppm	277.88	39.51	n.s.	n.s.	296.44	87.90	n.s.	n.s.
Mn total ppm	54.22	12.2	n.s.	n.s.				
Cu total ppm	10.51	1.09	n.s.	n.s.				
Zn total ppm	7.32	0.55	*	*				

Significant differences: a between treatments; b within replicates; c over the course of time (Jun. 1998 to Jan. 1999)
n.s.: not significant; * significant on the 5 % level
by SAS GLM[1] and mixed procedure[2]

The question arises whether these differences have a significant influence on the measured growth parameters between the treatments. “Phosphorus is a constituent of phosphatides like nucleic acids, phospholipids and co-enzymes. Phosphorus is important for cell division and functions as a carrier in high energy transformations. A deficiency of phosphorus usually results in stunted growth of the tea plant and the mature leaves show a characteristic bluish green coloration. Symptoms of phosphorus deficiency have not been observed in Sri Lanka” (TRI, 1986). Phosphorus surplus in the soil, e.g. supplied through fertilizer, which is not used by the plants, undergoes a transformation process into a stable phosphorus fraction until the soil is saturated, without negative effects for plant growth (Mengel, 1991). After manure application mean P amounts multiplied four times in the top and six times in the sub soil layer. Phosphorus supply is sufficient for normal plant growth at the study site. “Zinc is categorised as one of the essential elements for plant growth and necessary for the synthesis of the plant hormone, indole acetic acid which is responsible for active shoot growth”. Zinc deficiency in tea usually results in distorted “sickle shaped” leaves, which are sometimes discoloured. The affected bushes are often dormant, lacking new flush growth (TRI, 1986). Zinc content was within the acceptable range and no zinc deficiency symptoms were observed. Therefore it is concluded that no specific influence on measured growth parameters from the original phosphorus and zinc status of the soil are considered as being more important than the used organic amendments.

Optimum pH range for tea cultivation is given with 4.5 – 5.5 (TRI, 1986). The pH at the trial field was quite high and needs to be considered as a possible impediment when comparing the growth rate of the plants with other locations. Application of bioslurry caused an obvious decrease in pH on top and sub soil level. Observations by Stoer (1995) confirm, the continued use of bioslurry in one area tends to make soils acidic, which in the case of tea can be beneficial.

Statistical comparison of the soil status between June 1998 and January 1999, using the mixed procedure of SAS, showed a significant time effect for the total N and P content on top and sub soil level and organic carbon in the sub soil level (Tab. 14). Until January 1999 mean pH decreased without showing significant differences between treatments and over the time (Tab. 14). Total amounts of N, P and carbon rose without showing significant treatment effects, implementing similar changes through the application of different organic manure. Original significant differences in P content were levelled out (Fig. 14).

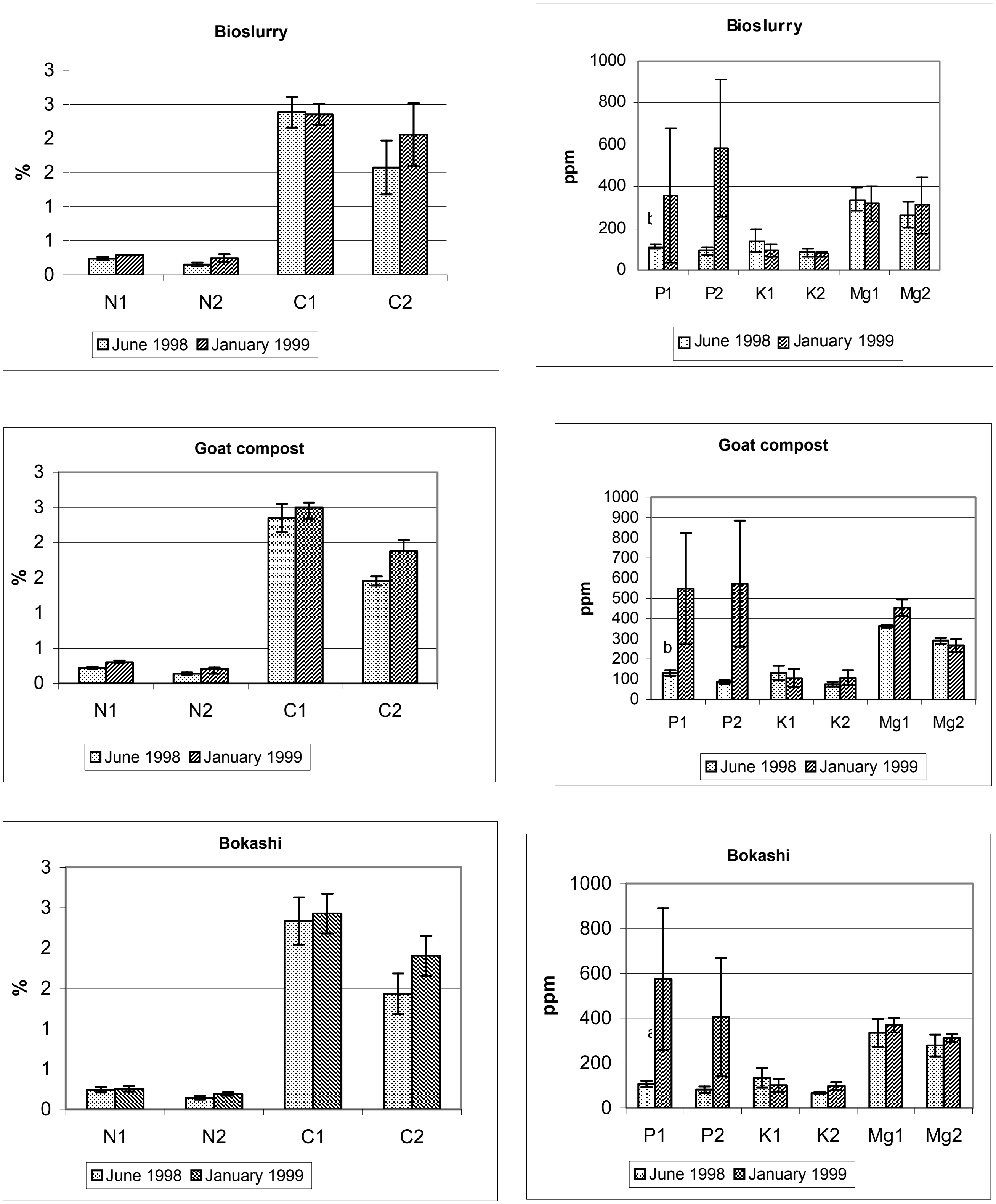

Fig. 14 Changes in soil nutrient status on top (1) and sub (2) soil level between June 1998 (before) and January 1999 (after) the application of organic manure (15. Jun.1998; 8. Oct.1998) on a young tea field at Udapalatha, Kandy District, Sri Lanka (all values are means of three mixed soil samples)

7.3.2 Growth assessment

There were no significant differences regarding the measured growth parameters between the three treatments at the beginning of the trial in June 1998 indicating uniform starting conditions regarding the plant material over the experimental area (Fig 15-18). Plant height increased by an average of two cm (1.96) until December 1998 without significant differences between the treatments. Plant height was not considered further as tea plants were given a “cut across” at 9 inches (□ 23 cm) to encourage lateral growth for bush formation in April 1999. In December 1998 the average diameter over the three treatments was 4.4 mm with significant differences between BS and BK treatments, indicating higher growth rates for the bioslurry treatment. In June 1999 the average diameter increased to 4.9 mm with significant differences between GC on the one side and BS and BK on the other side, indicating a lower growth rate of the goat compost treatment. The mean values of measured diameter between treatments at different times showed highest growth rates for the bioslurry treatment over the course of one year. In December 1998 the average number of leaves per plant over the three treatments was 13.8 with significant differences between BS and GC, BK, indicating higher growth rates of the bioslurry treatment. After the first drought season in April 1999 average number of leaves per plant dropped down to 9.9 again showing significant differences between BS and GC, BK,. Nevertheless until June 1999 plants recovered and the average number of leaves per plant increased to 19.8 keeping significant differences between BS on the one hand and GC and BK on the other. Analysing the mean values of leaves between treatments at different times (e.g. Z2 minus Z1) showed no significant growth differences between the three treatments after December 1998. Until June 1999 the average number of primary side branches increased to 3.3 with significant differences between BS and BK indicating higher growth rates for the bioslurry treatment. Data regarding diameter and number of primary side branches was also subject to analysis of variance considering block effects. Comparison of the mean block value between the three blocks in December 1998 and June 1999 showed no significant block effects indicating uniform growth conditions over the three blocks.

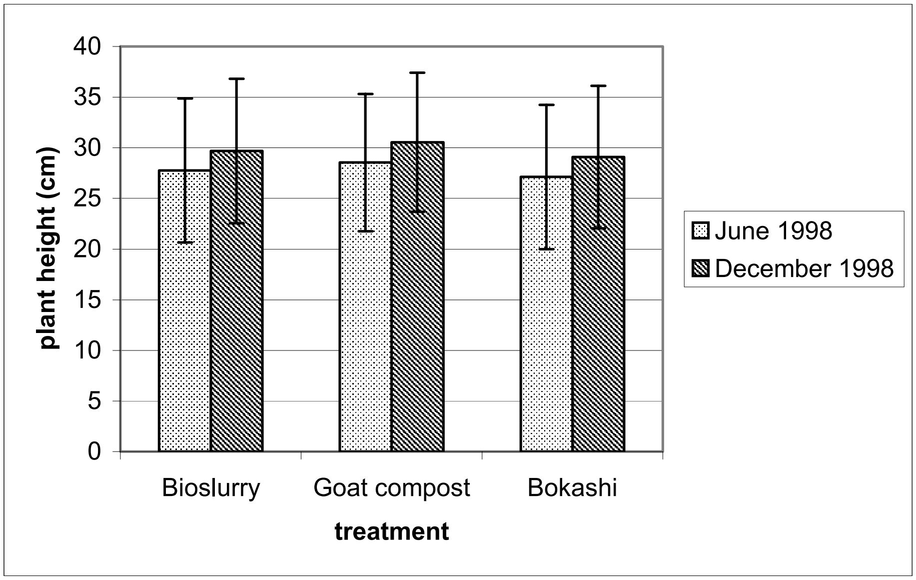

Fig. 15 Mean plant height of *Camellia sinensis* at the time of planting and six months later (first year in the field). Growth comparison with three organic amendments.

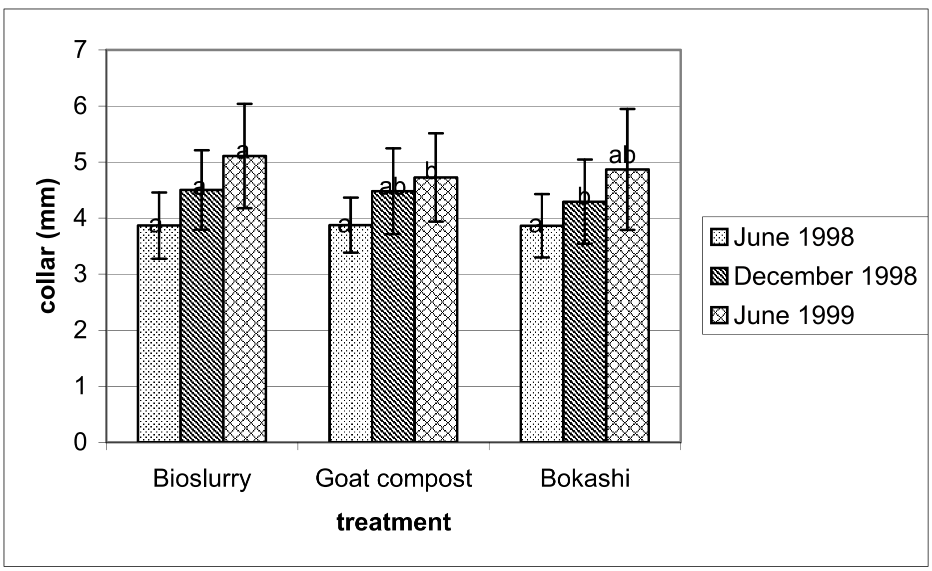

Fig. 16 Mean diameter of the collar 1 inch (2.54 cm) above soil level of *Camellia sinensis* at the time of planting and 6 respectively 12 months later (first year in the field). Growth comparison with three organic amendments. Means of the same time with the same letter are not significantly different.

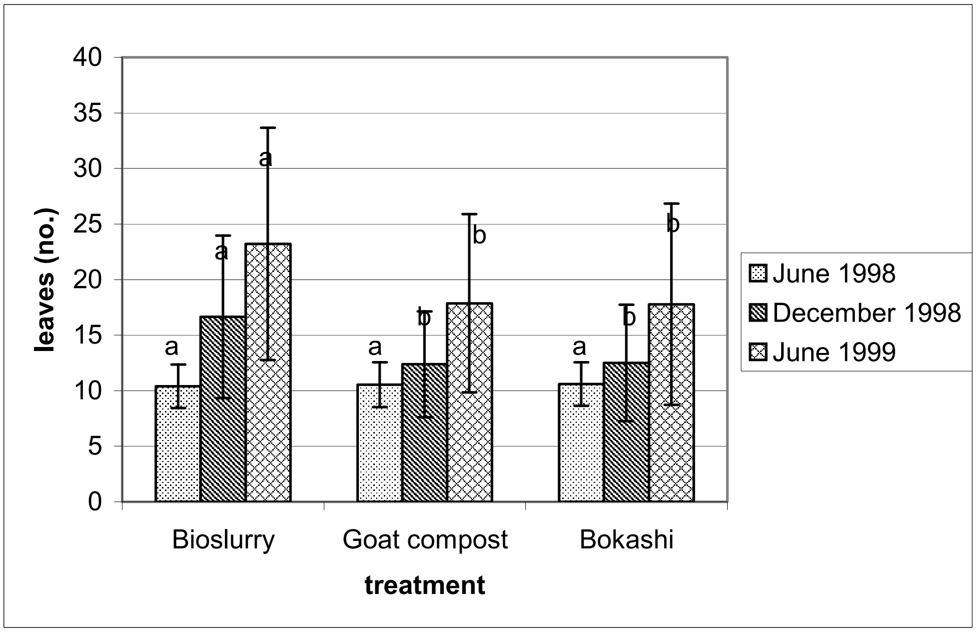

Fig. 17 Mean number of leaves of *Camellia sinensis* at the time of planting and 6 respectively 12 months later (first year in the field). Growth comparison with three organic amendments. Means of the same time with the same letter are not significantly different.

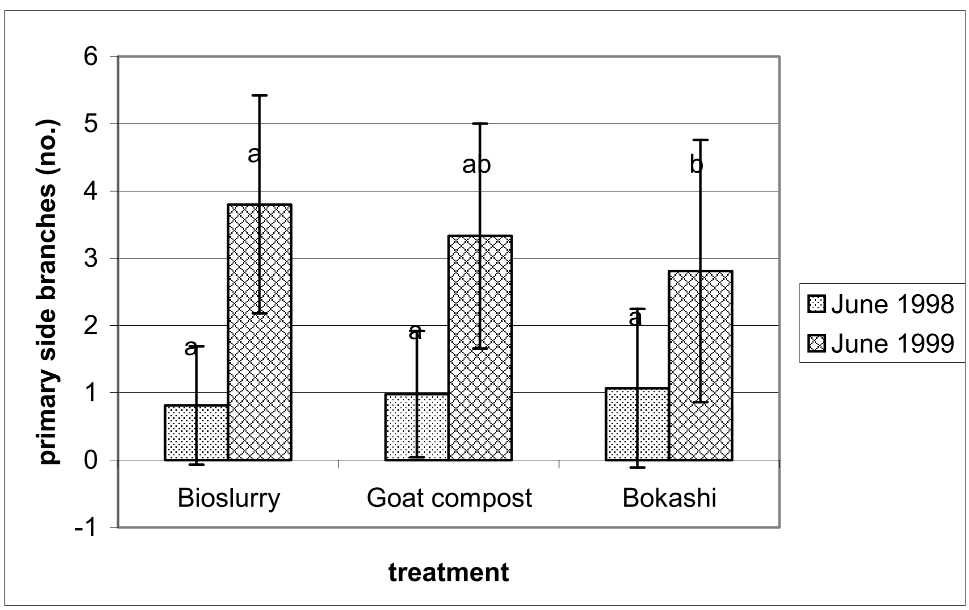

Fig. 18 Mean number of primary side branches of *Camellia sinensis* at the time of planting and one year later (first year in the field). Growth comparison with three organic amendments. Means of the same time with the same letter are not significantly different.

After establishment of plants the first new shoots were visible in August 1998. Mean values of new shoots ascertained at the same time showed only significant differences between treatments in October and November 1998, where the bioslurry treatment showed a significant higher number of new shoots than the goat compost respectively bokashi treatment (Fig.19). During the drought season from January until March 1999 plants matured and growth rested. In April 1999 first new shoots appeared and showed significant differences in number between bioslurry and bokashi. Analysis of variance for repeated measures of shoot growth showed that first there is a significant treatment effect (T) secondly there are significant differences over the course of time (Z) and thirdly there are significant treatment effects in shoot growth over the course of time (T*Z). The mean number of new shoots between treatments at different times showed highest growth rates for the bioslurry treatment and lowest for bokashi. Regarding the number of plants with new shoots, significant univariate differences in means show a time effect.

The co-variance analysis with phosphorus (T*P) and zinc (T*Zn) showed no significant effects (F_P = 0.89; F_{Zn} = 0.64) of the nutrients regarding shoot growth between the three treatments over the course of time.

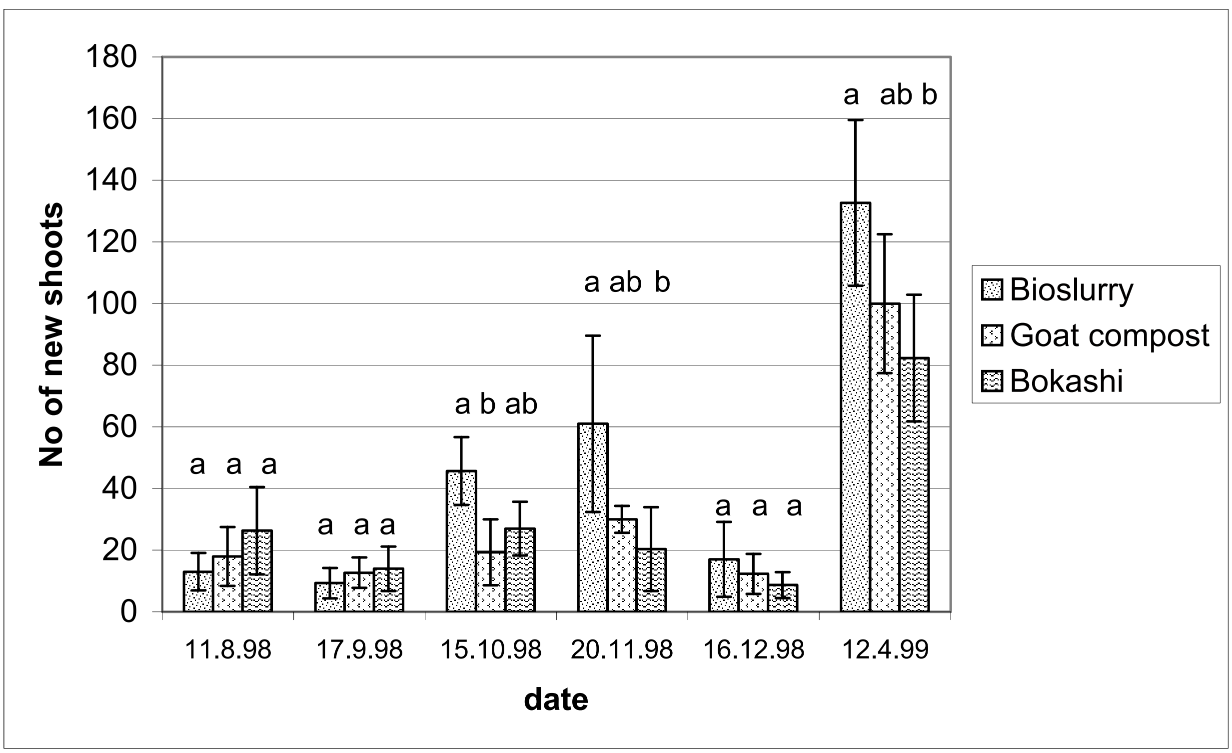

Fig. 19 Effect of three organic amendments on the shoot growth of *Camellia sinensis* planted in June 1998 (12 months old vegetative propagated plants).

7.4 Conclusions

The use of organic amendments to improve soil fertility and plant growth is a well known and adapted agricultural practice, also in tea cultivation. Poor availability of materials in some areas justifies the search for additional suitable organic inputs. Results of the present study showed that bioslurry has the potential to add sufficient amounts of N and K to the soil in order to sustain growth of young tea plants, when applied at a rate of 98 t ha^{-1} yr^{-1} fresh matter. Further plant growth assessment over the course of one year showed a trend, indicating higher growth rates for the bioslurry treatment when compared with compost treatments. With the addition of mana grass mulch sufficient quantities of P and the trace elements were provided and the least amount of casualties occurred in this treatment. In 1937 Sir Albert Howard observed obvious improvements in the growth, vigour and health of tea plants fertilised with 12.5 t ha^{-1} compost made following the Indore method. Microscopic investigations showed that the mycorrhiza development on young tea roots grown with compost was much higher than of those grown with artificial fertilizer (Howard, 1979).

Stoer (1995) measured average daily output of bioslurry per adult cow of approximately 90 litres. Operating a 6 m^3 biogas plant with 3 cows has the potential to produce 97 t fresh slurry and 504 m^3 biogas per year. Attachment of a toilet will increase output. Optimum usage of bioslurry at a tea smallholder site would be through a controlled drainage system from the outlet into the field. Since nitrogen in the bioslurry is mainly present in the form of ammonia, volatile losses should be reduced through the final application of mulch or soil. Force feeding large amounts of bioslurry can increase the accumulation of toxic nitrogen compounds in the plant and tends to make soil acidic. Therefore various methods of use (fresh slurry, dried slurry, compost) should be practised at the same time serving different cultures and production periods.

8 Effect of organic amendments on the yield of *Camellia sinensis*

8.1 Introduction

This part of the study aimed to investigate the effects of bioslurry in comparison with compost on the yield and nutrient status of a mature tea field. Investigations were carried out under field conditions by analysis of soil, leaf and manure samples and field nutrient balance calculation. The field research was carried out in co-operation with the Tea Research Institute of Sri Lanka (TRI), Talawakele and the small farmers co-operative Gami Seva Sevana (GSS), Galaha.

8.2 Material and methods

8.2.1 Set up of field experiment

A mature organic tea field (1 acre = 0,4 ha) with a tea stand of 1207 bushes of the clone T 2026 planted in 1991 at the smallholders co-operative GSS was used for yield comparison. Two sections with 200 bushes each were marked and manured separately. One section with 5 l fresh bioslurry (30 t ha^{-1}) and respectively the other one with 6 kg fresh compost (36 t ha^{-1}) per plant in July and December 1998. Compost was incorporated in small trenches cut between the tea rows and bioslurry was poured into forking holes. Over a period of 4 months (Oct. 1998 - Jan. 1999) weekly yield levels from the two sections were recorded. The remaining tea plants were manured with compost as above and total yield level of the tea field recorded over a period of two years. To calculate the nutrient flow soil and leaf samples were taken for standard analysis before and after manuring.

8.2.2 Climatic conditions

Monthly rainfall data from Galaha Estate (approximately 6 km south of the research site) showed a peak in November 1997 and a drought situation from March to June 1998 (Fig. 20). Whereas during the second year of field research from July 1998 until June 1999 precipitation was distributed more evenly. Rainfall variation was clearly reflected on green leaf yield levels of tea.

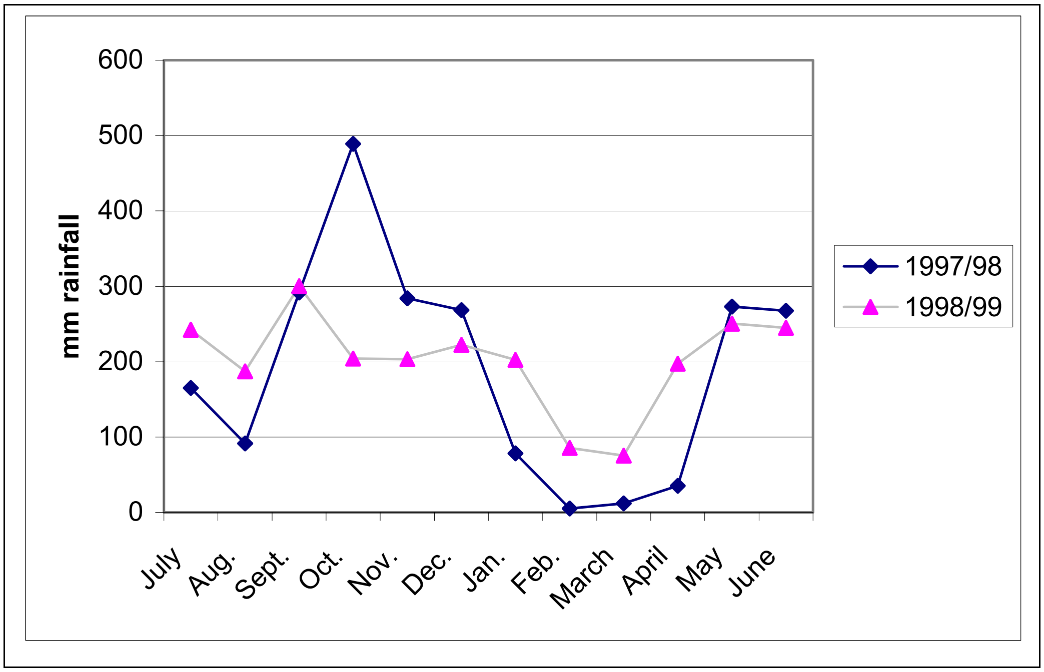

Fig. 20 Monthly rainfall data from Galaha Estate, Kandy District, Sri Lanka

8.2.3 Chemical analysis and nutrient determination of soil, manure, leaf and mulch samples

To evaluate the initial soil chemical properties, bulked soil samples (5 single cores) were taken from each plot with an auger (2 cm diameter) to a depth of 30 cm (0-15 cm top soil, 15-30 cm sub soil) prior to manuring. Soil sampling was repeated as above in January 1999 to evaluate changes in the soil chemical composition. Standards given by Pagel et al. (1982), Scheffer & Schachtschabel (2002) and TRI (1995) were used for characterization and comparison of the described soil parameters. Fresh manure samples were taken once at the time of manuring (June 1998). To calculate the nutrient field balance of the mature tea field soil and leaf samples were taken before (May 1998) and after (January 1999) manuring. The elemental composition of all the samples was determined by standard methods of analysis at the TRI Talawakele and Galle laboratories.

8.3 Results

8.3.1 Soil nutrient status

Analytical results from mixed soil samples taken from a mature tea field before manuring in May 1998 showed a low nutrient status for N and K in the top and for P in the sub soil layer. After the amendment of bioslurry soil analytical results improved within the acceptable range for N and many times over for P and Mg. The K-level declined in the top soil layer but more than tripled in the sub soil layer. The compost amended section also showed improved nutrient status, keeping low K values (Tab. 15).

Tab. 15 Soil nutrient status of a mature organic tea field before (May 1998) and after (Jan. 1999) the addition of organic amendments

		N %	P ppm	K ppm	Mg ppm
	Optimum level *	0.2-0.3	10-20	80-200	>60
Top soil 0-15	May 1998	0.11	25	64	252
	Jan. 1999 bioslurry	0.3	732	53	538
	Jan. 1999 compost	0.22	156	78	463
Sub soil 15-30	May 1998	0.07	6	44	150
	Jan. 1999 bioslurry	0.24	209	158	414
	Jan. 1999 compost	0.25	155	68	481

* TRI, 1995

8.3.2 Manure nutrient status

Compost was made from cow manure, the remaining materials from the roughage feed given to the cows and garden waste. Cow and pig excreta passing through a biogas plant, undergoing an anaerobe digestion process for about 70 days are referred to as bioslurry. Analysed nutrient contents (Tab. 16) were similar to findings given by Müller-Sämann (1986), FAO (1987), Stoer (1995).

Tab. 16 Composition of organic amendments from the mid country of Sri Lanka, 1998

Organic amendments	Moisture (%)	DM (%) N	P	K	Mg	C_{org}	C:N ratio
Compost	51	1.90	1.2	0.52	0.87	30.2	16
Bioslurry	97	1.72	0.4	0.35	0.25	30.5	18

TRI analysis 1998

8.3.3 Leaf nutrient status

Analytical results from the leaf analysis (Tab. 17) show low N, P and K contents in the mother and maintenance leaves and acceptable values for two & a bud in May 1998. For mother and maintenance leaves N and K contents increased after the application of organic amendments and P content stagnated on a low level in January 1999. While N content of two & a bud in the bioslurry treatment increased, P, K and Mg contents decreased, whereas in the compost treatment N, P and Mg contents decreased and K content increased. It appears that manuring mainly improved the N and K status of mother and maintenance leaves.

Tab. 17 Nutrient content of tea leaves (*Camellia sinensis*) from a mature organic tea field before and after manuring. The tea field was planted in 1991 in Kandy District, Sri Lanka and manured with 30 t ha^{-1} bioslurry and 36 t ha^{-1} fresh compost in July and December 1998.

		N%	P%	K%	Mg%
Two & bud	May 98	4.24 $_A$	0.27 $_A$	1.45 $_A$	0.33 $_A$
	Jan. 99 bioslurry	4.5 $_A$	0.12 $_L$	1.24 $_L$	0.22 $_A$
	Jan. 99 compost	4.1 $_A$	0.13 $_L$	1.56 $_A$	0.27 $_A$
Mother leaf	May 98	2.51 $_L$	0.13 $_L$	0.5 $_L$	0.61 $_A$
	Jan. 99 bioslurry	3.1 $_A$	0.14 $_L$	1.4 $_A$	0.3 $_A$
	Jan. 99 compost	3.0 $_A$	0.13 $_L$	1.61 $_A$	0.29 $_A$
Maintenance leaf	May 98	2.56 $_L$	0.14 $_L$	0.55 $_L$	0.54 $_A$
	Jan. 99 bioslurry	2.7 $_L$	0.13 $_L$	1.24 $_L$	0.23 $_A$
	Jan. 99 compost	3.0 $_A$	0.15 $_A$	1.63 $_A$	0.29 $_A$

$_A$ within an acceptable range, $_L$ low nutrient content

8.3.4 Green leaf harvest

Comparing the total green leaf yield levels of the mature tea field from July 1997 until June 1998 (628 kg) with the following year from July 1998 until June 1999 (710 kg), total yield increased by 11.5 % after manuring took place (Fig. 21). Harvest of green leaf per plant increased from 520 g (97/98) to 588 g (98/99). Yield comparison between the two sections manured with bioslurry and compost over a period of four months showed similar yield levels (77.8 and 75 kg / 200 plants) for the two treatments.

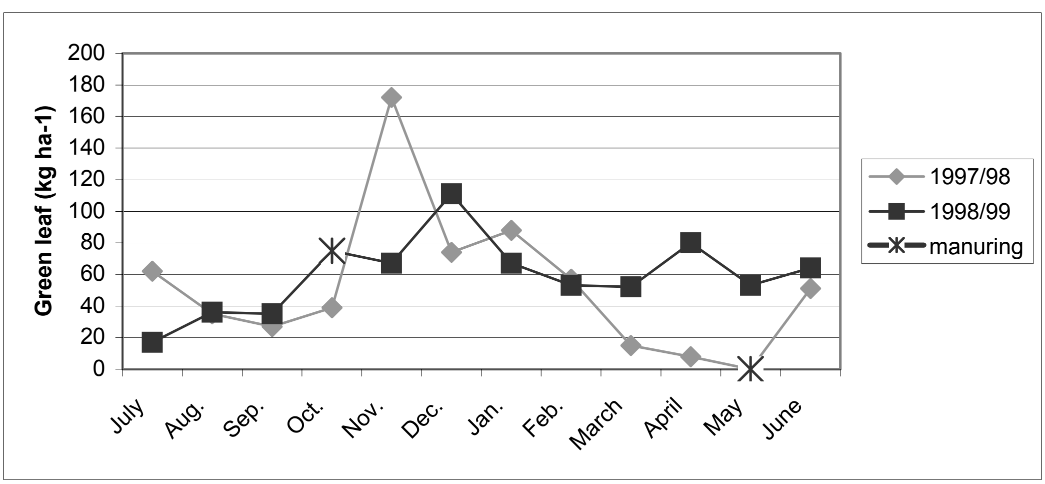

Fig. 21 Monthly green leaf yield of a mature organic tea field planted in 1991 in Kandy District, Sri Lanka

8.3.5 Field nutrient balance

Nutrient import was calculated as the amount of nutrients incorporated with the organic amendments on dry matter basis (1,207 plants times 10 kg bioslurry / 12 kg compost) considering NH_4^+ and K^+ content of fresh slurry. Nutrient export was calculated from leaf nutrient content of actual harvest figures with moisture content of 76.2 % (Tab. 18). Simple field nutrient balance is even for the bioslurry treatment and positive for the compost treatment.

Tab. 18 Nutrient import through the amendment of compost (14.4 t FM) and bioslurry (12 t FM) and nutrient withdrawal through the export of harvested green leaf (710 kg FM) over a period of one year (May 1998 – April 1999) from a mature organic tea field (0.4 ha) planted in 1991 in Kandy District, Sri Lanka

Treatment	kg Dry matter				kg Fresh matter	
Bioslurry	N	P	K	Mg	NH_4^+	K^+
Nutrient import manure	6.2	1.4	1.2	0.90	24	36
Nutrient export leaf	7.6	0.2	2.0	0.37		
Balance	-1.4	1.2	-0.8	0.53	24	36

Treatment	kg Dry matter			
Compost	N	P	K	Mg
Nutrient import manure	135	85.0	37.0	62.00
Nutrient export leaf	7	0.2	2.6	0.45
Balance	128	84.8	34.4	61.55

8.4 Discussion

Results showed that bioslurry and compost have the potential to maintain and improve the soil and leaf nutrient status and the yield of a mature organic tea field. However the field nutrient balance neglects the nutrient uptake for plant growth of states approximately 57 kg N ha^{-1} year^{-1} (Franke, 1994), volatile losses of 50 kg N ha^{-1} year^{-1} and 18 kg N ha^{-1} year^{-1} being washed out (Barua, 1989). Considering these factors bioslurry application of 10 l per plant year^{-1} was not sufficient for a sustainable growth of mature tea plants whereas compost application met the requirements. Operating a 4m^3 biogas plant with 2 cows has the potential to produce 64 t fresh slurry per year. Slurry output would be sufficient to manure 3,000 tea plants. Variation and adaptation of fertilizer application for a balanced nutrient supply under local circumstances is recommended e.g. for compost application of 12 t ha^{-1} every four years in combination with yearly bioslurry application of 15 l per plant through a drainage system. Further integration of legumes for N accumulation and recycling is recommended.

9 Comparison of microbial biomass activity in a Red Yellow Podsolic (RYP) soil grown with tea after the addition of organic amendments

9.1 Introduction

Microbial biomass is defined as the part of organic substance in the soil, which consists of micro-organisms. Microbial parameters like respiration, ATP-content and heat output give quantitative information about the productivity of microbial populations in the soil. They express the physiological situation of the cells, being affected and regulated by different environmental factors. So far all methods to measure the microbial biomass can only give estimated values (Alef, 1991; Fairbanks et al., 1984; Nannipieri et al., 1978; Ross & Tate, 1984; Shen et al., 1987). Investigations at a newly planted tea field showed how microbial biomass activity varied with application of different organic manures.

9.2 Material and methods

9.2.1 CO_2 Evolution – state of the art

Laboratory experiments were conducted regarding the soil microbial activity and root respiration after the incorporation of organic materials at a tea field planted in June 1998. Mixed soil samples of three treatments (bioslurry 2.9 t ha^{-1} DM, goat compost 48 t ha^{-1} DM, bokashi 63 t ha^{-1} DM) manured in June and Oct. 1998 along with sterilized soil for comparison were taken in August 1999 to measure the CO_2 evolution under field conditions (Isermeyer, 1952). In October 1999 CO_2 evolution measurement under field conditions was repeated from bales of uprooted plants measuring soil and root respiration. Microbial biomass experiments were conducted at the laboratory of the Soil Department, University of Peradeniya, Sri Lanka and TRI stations Hantana and Talawakele.

9.2.2 Cumulative CO_2 evolution

After addition of organic amendments the cumulative CO_2 evolution (Isermeyer, 1952) was measured under laboratory conditions using Red Yellow Podsolic soil (RYP) collected from Nava Nillambe area. Soil samples were sieved through a 2 mm sieve at field moisture level and moisture content was adjusted to 40 % of the maximum water holding capacity. Three organic amendments were added separately to the soil (50 g) at the rate of 47 t/ha dry matter goat compost, 15 t/ha DM bokashi and 1.8 t/ha dm bioslurry. Soil (RYP) without any addition of organic material was used as a control treatment. The following four treatments were analysed: 1. soil alone (control); 2. soil + bioslurry; 3. soil + goat compost; 4. soil + bokashi. From each treatment samples were drawn at 3/7/14/21and 28 days after incubation.

9.3 Microbial biomass results

9.3.1 CO_2 Evolution – state of the art

No significant statistical differences of the microbial biomass activity between the three treatments could be observed. Analytical results from August 1999 could be verified in October 1999 (Fig. 22). Microbial activity was found highest in soil amended with goat compost followed by bioslurry and bokashi and lowest in sterilized soil. Root respiration compared between the three treatments was found highest in the bioslurry treatment and lowest in the goat compost treatment (Fig. 23).

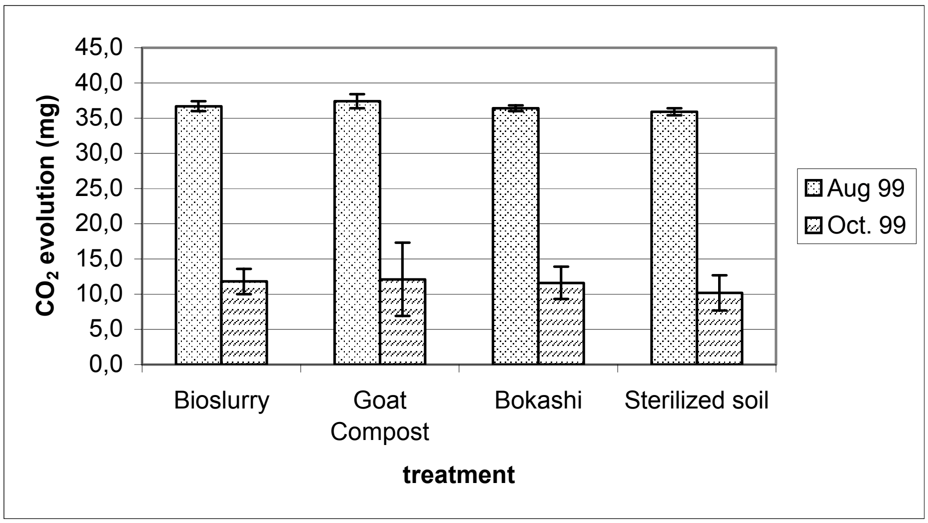

Fig. 22 Microbial activity in organic matter amended soils grown with tea in August 1999 (means of four replicates) and October 1999 (means of six replicates)

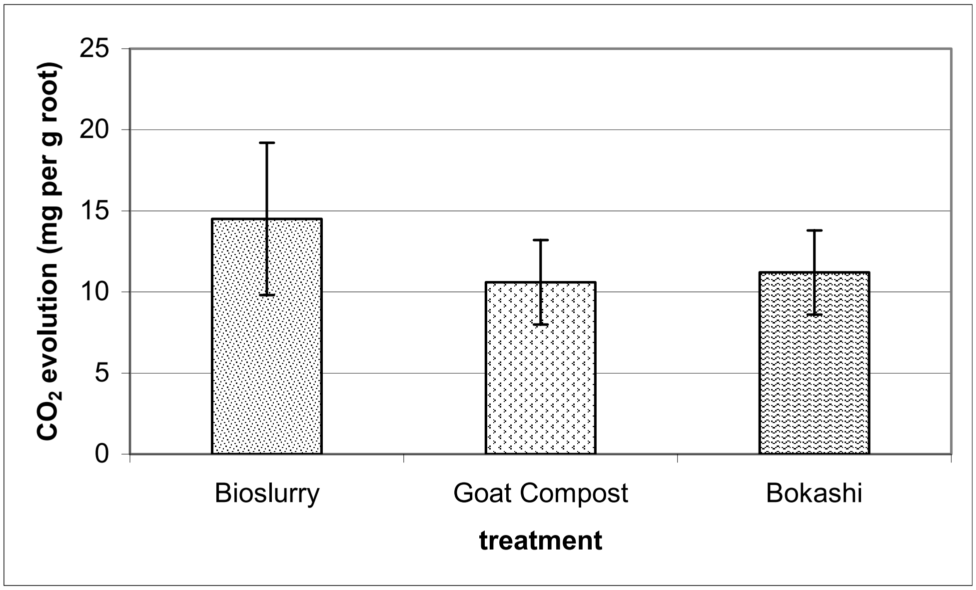

Fig. 23 Root respiration of tea grown in organic matter amended soil (means of six replicates) October 1999

9.3.2 Cumulative CO_2 Evolution

It was found that during the incubation period the cumulative CO_2 evolution from the microbial respiration was similar in pure soil and soil + bioslurry and much higher in soil amended with goat compost and bokashi (Fig. 24). Analysis of variance showed no significant differences in microbial activity between sterilized soil and soil amended with bioslurry during the incubation period. Goat compost and bokashi treatments show significant differences from each other and the remaining treatments.

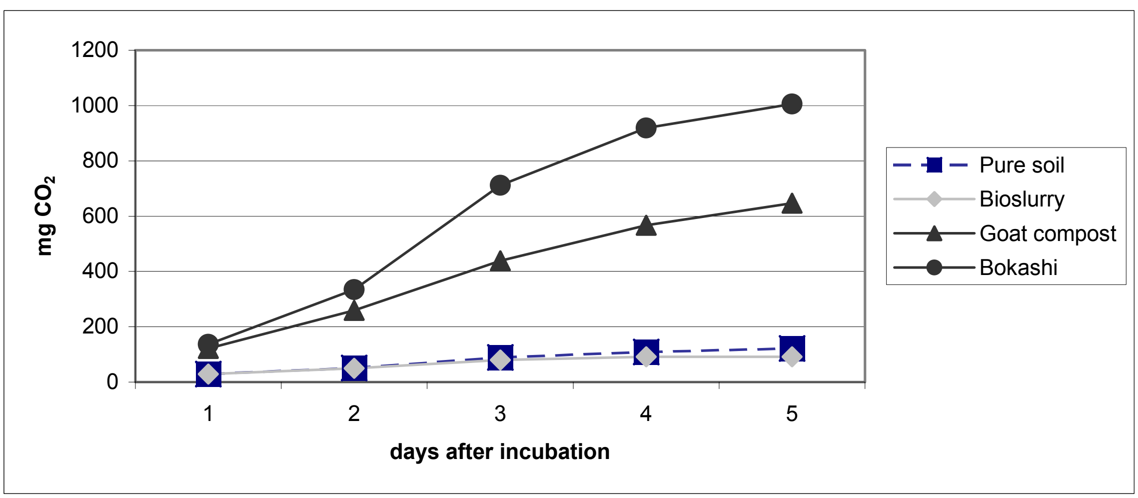

Fig. 24 Cumulative CO_2 evolution of organic matter amended soil during incubation period (means of three replicates)

9.4 Discussion

Biomass specific respiration reflects the activity of biomass in the soil. The size of the effective biomass increased with increasing decomposable soil organic matter content. With a C:N ratio of 7 and 8.5 bokashi and goat compost were subject to fast microbial decomposition. Therefore, the activity of biomass rapidly increased until easily decomposable materials were consumed. Witter et al. (1993) reported that soil specific respiration measured at 25 °C was highly correlated (r = 0.934) with organic carbon content of the soil. With 30.5 % organic carbon bioslurry had a higher C:N ratio of 17.7 than the other two treatments. Low microbial activity under laboratory conditions does not reflect the field results.

In depth research by Mohotti (1998) has shown that locally available organic soil amendments proved to be promising in bringing down populations of *Pratylenchus loosi*. The microbial activity of organic matter amended tea soils showed a strong correlation (R2 = 0.87) with free living nematode populations. Organic matter addition helped in activation and enhancement of nematode antagonists naturally present or introduced into the soil. Waste tea materials showed the most useful features. Effective and potential use of organic soil amendments as non-chemical substitutes in nurseries and mature tea fields was demonstrated.

Part IV Model farm

10 Design of an organic tea small holding as a model for sustainable tea production under mid country conditions in Sri Lanka

10.1 Introduction

Traditional subsistence agriculture has been practised for nearly 2000 years in Sri Lanka and throughout this period farmers have maintained an ecologically rich and diverse landscape. More than 1.3 million traditional home gardens in different agro-ecological zones of Sri Lanka covering an area of 626,170 ha have been maintained over the course of time (Kumar, 1998). In the mid country of Sri Lanka Kandyan Forest Gardens (McConell, 1992; Perera & Rajapakse, 1991; Hochegger, 1998) have played a key role in biodiversity conservation, building biological corridors and mosaic structures into the agricultural landscape. Since traditional home gardens are not maintained for cash crop production, today necessary income generation is mainly achieved through off farm employment. With colonialism plantation management was introduced. Tea planting started in the mid country of Sri Lanka in 1867 by clearing virgin forest and replacing uneconomical coffee sites. Since then Sri Lanka's agriculture has been characterized by two sectors of opposite structure existing next to each other. Plantation management dominating tea, rubber and coconut production on the one hand and smallholder farming on the other hand. Through land reforms in the 1970s uneconomical mid country tea land was distributed among landless people and former plantation labourers. After building a house and vegetable garden the average plot size (0.2 – 0.4 ha) was too small to generate income from tea cultivation on the remaining area. Further mainly marginal land with steep slopes was distributed and no necessary infrastructure program followed to support the new farmers. Additional constraints for agricultural development have been uncertain ownership patterns and the excessive fragmentation of agricultural lands. Farmers affected by the above mentioned circumstances have to secure income through off farm employment.

So it becomes obvious that land migration for off farm employment has become a serious problem. But the smallholder production is of crucial importance for the countries' self subsistence, rural economy and biodiversity conservation. According to the ADB (1994) about 65 % of the tea smallholders (TSH) in Sri Lanka cultivate other crops like paddy (47 %), rubber (27 %), coconut, pepper, cloves and cinnamon (26 %) besides tea. Sellathurai (1997) stated a high plant density of 1,883 plants ha^{-1} including 948 woody perennials and an average richness of 57 species per home garden. More than one million rural residents, or 6 % of the total population, rely on tea growing or processing for their livelihood. The tea sector has shown a considerable growth over the last two decades and the smallholders share in the national output of tea increased from 54 % in 1997 to 61 % (170,800 t made tea) in 2002 (CBS, 1998 a; CBS, 2002).

Further the TSHs are responsible for 70 % of the value of all the tea produced in Sri Lanka (ADB, 1998). The average yield of the conventional smallholder sector amounted to 2,286 kg ha^{-1} a^{-1} made tea compared to 1,462 kg ha^{-1} a^{-1} in the estate sector (CBS, 2002).

Comprehensive study of organic tea smallholder sites in the mid country of Sri Lanka, Kandy District gave the incentive to design a location specific sustainable tea smallholder site, matching production goals as close as possible to the resource base. Consequently base data was taken from own surveys and supported by literature. Following organic principles, the model combines plant production with tea as the main cash crop and animal husbandry with fodder supply, implying that in the long term at this location, the combination of crops and livestock can support more people per area unit in terms of calories and protein than either of the components alone. Farm set up was arranged on a typical slope around a biogas plant. From the investigated 529 farms an average farm size of 0.47 ha was chosen for the model farm and economical evaluation. The planning and design of this sustainable farm set up was a process that involved multiple criteria for system success and sustainability in a situation that changes over time and space. Thus the conceptual model discussed only allows identification and quantification of important issues and calls for individual alterations.

10.2 Material and methods

10.2.1 General farm set up

From the survey data an average farm size of 0.47 ha on sloping land accommodating a farm family of 6 people was chosen for the model farm (Fig. 25, 26). General farm set up includes a house (60 m^2), stable (24 m^2), goat shed (12 m^2) and biogas plant with a volume of 4 m^3 and production of 64.8 t $year^{-1}$ bioslurry and 350 m^3 $year^{-1}$ biogas situated at the upper part of the garden. Animals kept are two cows, two calves, four goats and six chickens. As cash crops about 3000 tea plants are cultivated in a mixed cropping system with pepper vines (*Piper nigrum*) supported by betel nut palms (*Areca catechu*) and gliricidia trees (*Gliricidia sepium*). An area of 200 m^2 is used for fodder grass production. On the remaining area along the borders, around the house and surrounding the tea field various plants of economic value are grown. These are cultivated in a multi-story mixed cropping system with average species richness of 41 per 0.47 ha (Tab. 6). Integrated trees and shrubs are also used as fodder and for mulching. At the biogas plant a tank is installed for bioslurry storage. Biogas is used for cooking and lighting. A toilet should be attached to the biogas plant to increase nitrogen input and efficiency (because of the cultural background so far not accepted). From the outlet of the biogas plant a drainage system is dug throughout the garden for easy distribution of liquid bioslurry. Drains run in between every second tea row so that alternative rows can be used for plucking. Compost heaps are built in the vicinity of the animal sheds. Fruit, spices and vegetables are cultivated close to the house for easy caring and protection. Average work hours were taken from sample farms and own experience. Costs of production were calculated with actual market prices.

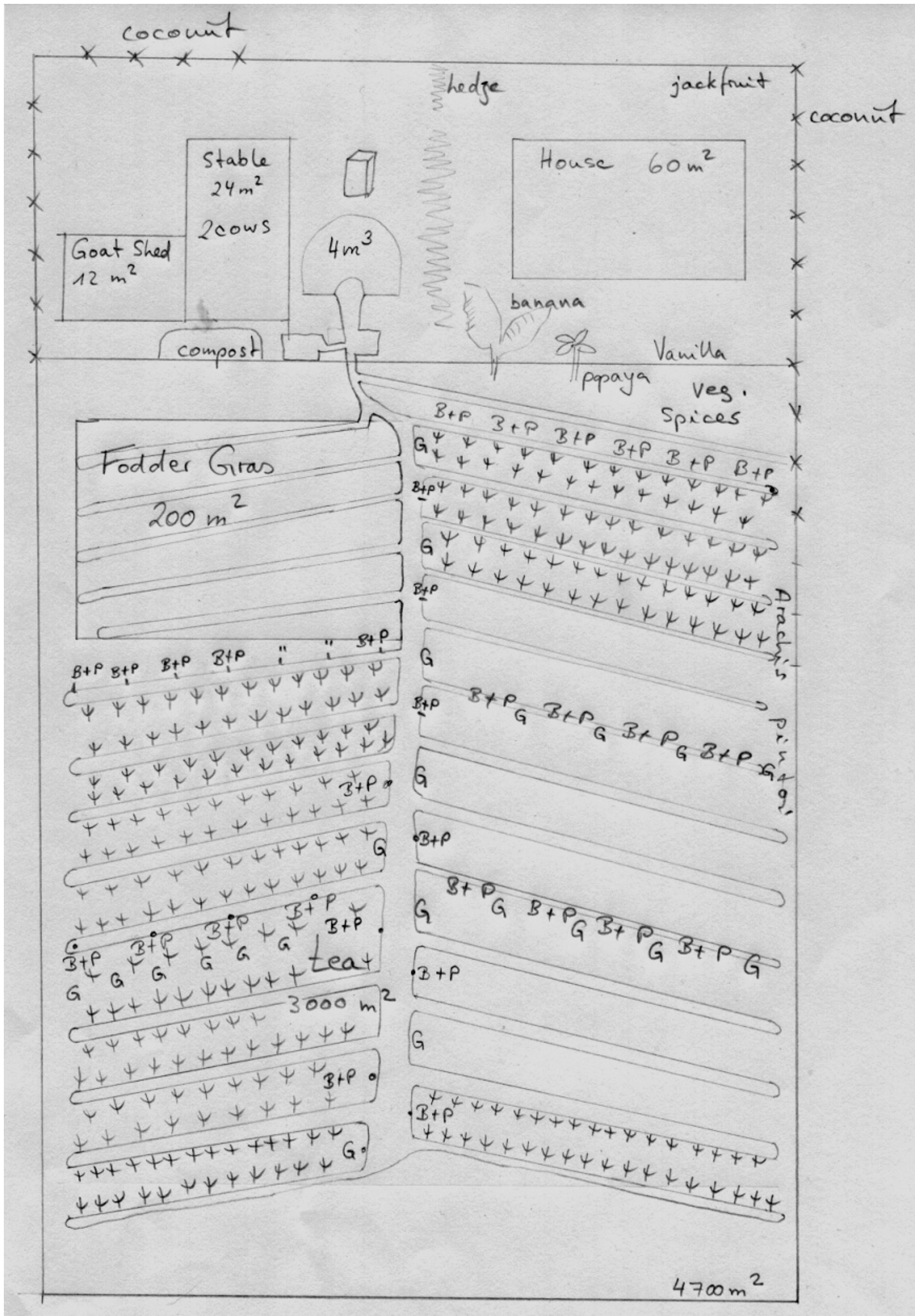

Fig. 25 Model of an organic tea smallholder site for the mid country of Sri Lanka (B+P betelnut with pepper vines; G gliricidia)

Fig. 26 Design of an organic tea smallholder site for the mid country of Sri Lanka

10.3 Economic situation

10.3.1 Income generation

For the model farm fifteen species next to tea with a total of 165 plants and crop value of 14,550 SL Rs were chosen for market production (Tab. 19). Most of the produce is sold on the local market, so local farm gate prices were used for income calculation. At the moment mainly spices like chilli, pepper, cloves and vanilla have the potential to enter the international organic market, fetching higher prices than on the local market. Adding the income from surplus cow and goat milk sales annual income comes up to 93,885 SL Rs (Tab. 20).

Tab. 19 Market value of crops grown for income generation at a tea smallholder model farm in Kandy District, Sri Lanka

Botanical name	Family	English name	No of plants	Unit value SL Rs	Total SL Rs
Areca catechu	Arecaceae	Betelnut	56	90	5,040
Artocarpus altilis	Moraceae	Bread fruit	1	150	150
Artocarpus heterophyllus	Moraceae	Jack fruit	2	100	200
Capsicum spp.	Solanaceae	Chilli	10	30	300
Carica papaya	Caricaceae	Papaya	5	80	400
Caryota urens	Arecaceae	Toddy palm	2	800	1,600
Citrus limon	Rutaceae	Lemon	2	100	200
Cocos nucifera	Arecaceae	Coconut	20	100	2000
Mangifera indica	Anacardiaceae	Mango	2	700	1,400
Musa spp.	Musaceae	Banana	5	120	600
Myristica fragrans	Myristicaceae	Nutmeg	1	100	100
Persea americana	Lauraceae	Avocado	1	100	100
Piper nigrum	Piperaceae	Pepper	50	30	1,500
Syzygium aromaticum	Myrtaceae	Cloves	1	260	260
Vanilla planifolia	Orchidaceae	Vanilla	7	100	700
			165		14,550

Tab. 20 Income sources at a tea smallholder model farm in Kandy District, Sri Lanka

Income source	Annual income
3,000 tea plants with an average yield of 588 g per plant and year amount to 1,764 kg times 35 SL Rs	61,740 SL Rs
Yield of 165 plants with a market value (Tab. 19)	14,550 SL Rs
2 cows with an average surplus milk yield of 4 l each per day for 210 days amount to 1,680 l times 9 SL Rs	15,120 SL Rs
2 goats with an average surplus milk yield of 0.75 l each per day for 150 days amount to 225 l times 11 SL Rs	2,475 SL Rs
Total	93,885 SL Rs

10.3.2 Home consumption

Cultivation of plants for home consumption and barter economy plays a significant role for rural households. For the model farm 24 species with a total of 189 plants and an economical value of 1,864 SL Rs were identified to be grown for home consumption and barter economy (Tab. 21). Including home consumption of eggs and milk an equivalent monetary value of 7,279 SL Rs per year is produced on the farm (Tab. 22).

Tab. 21 Market value of crops mainly grown for home consumption and barter economy at a tea smallholder model farm in Kandy District, Sri Lanka

Botanical name	Family	English name	No of plants	Unit value SL Rs	Total SL Rs
Annona spp.	Annonaceae	Annona	1	80	80
Anthurium spp.	Araceae	Anthurium	2	1	2
Azadirachta indica	Meliaceae	Neem	4	1	4
Ceiba pentandra	Bombacaceae	Kapok	1	100	100
Coffea arabica	Rubiaceae	Coffee	5	40	200
Colocasia esculenta	Araceae	Taro	10	25	250
Coriandrum sativum	Apiaceae	Coriander	1	1	1
Curcuma domestica	Zingiberaceae	Turmeric	5	10	50
Dendrocalamus giganteus	Poaceae	Bamboo	1	1	1
Dioscorea spp.	Dioscoreaceae	Yam	5	25	125
Elaescarpus serratus	Elaeocarpaceae	Ceylon Olive	1	50	50
Elettaria cardamomum	Zingiberaceae	Cardamom	5	20	100
Erythrina variegata	Fabaceae	Indian cord tree	20	1	20
Gliricidia sepium	Fabaceae	Quick stock	100	1	100
Grevillea robusta	Proteaceae	Silver Oak	5	1	5
Michelia champaca	Magnoliaceae	Champak	5	1	5
Moringa oleifera	Moringaceae	Drum stick	2	15	30
Passiflora edulis	Passifloraceae	Passion fruit	1	80	80
Phyllanthus emblica	Euphorbiaceae	Emblic	1	1	1
Piper betel	Piperaceae	Betel leaf	1	30	30
Psidium guajava	Myrtaceae	Guava	1	100	100
Sesbania grandiflora	Fabaceae	Corkwood tree	2	260	520
Toona ciliata	Meliaceae	Indian mahagony	5	1	5
Zingiber officinale	Zingiberaceae	Ginger	5	1	5
			189		1,864

Tab. 22 Monetary equivalent of agricultural production for home consumption and barter economy at a tea smallholder model farm in Kandy District, Sri Lanka

Home consumption and barter economy	Market value
189 plants (Tab. 21)	1,864 SL Rs
1 l cow milk per day for 210 days amounts to 210 l times 9 SL Rs	1,890 SL Rs
0.5 l goat milk times 150 days amount to 75 l times 11 SL Rs	825 SL Rs
3 eggs per day at 300 days amount to 900 eggs times 3 SL Rs	2,700 SL Rs
Total	7,279 SL Rs

10.3.3 Costs of production

Investments into livestock (60,150 SL Rs) and a biogas plant including accessories (18,785 SL Rs) are main factors of costs (Tab. 23). Besides these long term investigations, costs for insemination and medical care (1,000 SL Rs) account on a yearly basis. Depending on the former farm set up and farmers cultivation skills investments into plant material, seeds, plant protection measures and organic fertilizer are optional and estimated as variable costs for plant production with 2,000 SL Rs (Tab. 24). The economical balance indicates a positive difference between inputs and outputs of almost 98,000 SL Rs per year (Tab. 25). If the production system is established, costs of production are low.

Tab. 23 Investment factors of a tea smallholder model farm in Kandy District, Sri Lanka

Factor	Price per unit (SL Rs)	Total costs (SL Rs)
Biogas plant 4 m^3	18,085	18,085
Gas stove	340	340
Gas lamp	180	360
Lactating cow	20,000-30,000	50,000
Lactating goat	5,000	10,000
Chicken	25	150
Total		78,935

Tab. 24 Annual costs of production for livestock maintenance and plant production at a tea smallholder model farm in Kandy District, Sri Lanka

Factor	Frequency	Price per unit (SL Rs)	Total costs (SL Rs)
Insemination 2 cows	Twice a year	75-200	300
Insemination goats	Fourth a year	50	200
Medical care animals	Twice a year	250	500
Plant production	Throughout the year		2,000
Total			3,000

Tab. 25 Economical balance

Factor	Output	Input	Difference
Income from production (Tab. 20)	93,885		
Home consumption, barter economy (Tab. 22)	7,282		
Animal / Plant production costs (Tab. 24)		3,000	
Total	101,167	3,000	+98,167

Input of labour for maintenance and harvesting is variable and difficult to estimate. Regarding the labour requirement at the model farm it is assumed that the farm family fullfills all the necessary farm work itself generating an imaginary income of 70,730 SL Rs. For the field work (Tab. 26) average daily work hours were calculated added up to 1.8 income receivers at a rate of approximately 120 SL Rs per day. Depending on the farm location extra time for walking to the milk collection centres twice a day, which is often combined with shopping, was not considered as a working hour.

If the difference of 27,437 SL Rs between the income from production (98,167 SL Rs) minus the asumed internal costs for labour (70,730 SL Rs) is used to cover the costs for long term investments (Tab. 23), theoretically the break even point could be reached after three years.

Tab. 26 Average annual labour requirement at a tea smallholder model farm in Kandy District, Sri Lanka

Factor	Activity	Time days*	Price per unit (SL Rs)	Total price
Tea	Plucking	48	100	4,800
	Weeding	16	120	1,920
	Maintenance	12	120	1,440
Cows & goats	Feeding, milking, cleaning	136 (3 h / day)	20	21,900
	Fodder collection	91 (2 h / day)	20	14,600
Chicken	Feeding, caring	22 (0.5 h / day)	20	3,650
Biogas plant	Correct feeding, outlet control, slurry distribution	45 (1 h / day)	20	7,300
General	Drainage maintenance	12	120	1,440
	Compost making	10	120	1,200
	Garden maintenance	52	120	6,240
	Harvesting of other crops (pepper)	52	120	6,240
Total		594		70,730

*working day of 8 hours / working year of 330 days

10.4 Fodder production

About 800 m^2 are reserved for fodder production. A field of 200 m^2 for growing fodder grass is established close to the animal sheds. Integration of *Desmodium ovalifolium* and *Pueraria phaseoloides* in combination with *Panicum maximum* has proved to be a productive mixture at the research site. Recommended fodder grass species are *Pennisetum purpureum* (80 t DM per year, Caesar 1986), *Panicum maximum*, *Tripsacum laxum* and *Brachiaria brizantha*. Fertilization and irrigation is provided through a drainage system. The remaining 600 m^2 are scattered throughout the garden, along the borders, in and around the tea sections and planted with multipurpose species of fodder value like *Tithonia diversifolia*, *Sesbania grandiflora* (variegata), *Gliricidia sepium*, *Calliandra callothyrsus*, *Crotolaria juncea* and *Leucaena leucocephala*. Experiments at the Soriyagoda extension centre of the TSHDA showed, that *Gliricidia sepium* established as a SALT hedge (Sloping Agriculture Land Technique) does not withstand continuous deep lopping (3 times a year) over a period of six years. Within the same experiment *Tithonia diversifolia* tended to form a big root base dropping into the drains if planted above the drains on a slope, whereas *Flemingia congesta* and *Calliandra callothyrsus* were well established SALT hedges (Somaratne, 1999 pers. communication). This experiment expressed the importance of appropriate cultivation techniques for the respective crops serving as fodder material and erosion control measure.

10.5 Nutrient balance

Nutrient import through the application of 64.8 t fresh bioslurry can support the growth and yield of 3,000 tea plants as the major cash crop (Tab. 27). Further nutrient recycling is achieved through the attachment of a toilet to the biogas plant, composting with the addition of bioslurry, mulching with *Tithonia diversifolia*, nutrient release of *Gliricidia sepium* litter (33 kg N, 0.6 kg P and 52 kg K per ha^{-1} $year^{-1}$) and N-fixation of *Arachis pintoi* grown as a cover crop.

Tab. 27 Nutrient import through the application of 64.8 t fresh bioslurry (97 % H_2O) per year on 0.47 ha and nutrient withdrawal through the yield of 1764 kg green tea leaf (75 % H_2O) (Stoer, 1995)

		N	P	K	Mg	NH_4^+	K^+
Import	%	1.7	0.4	0.35	0.25	0.2	0.3
slurry	kg	33	8	7	5	130	194
Export tea	%	4.5	0.12	1.24	0.22		
leave	kg	19.8	0.5	5.5	1.0		
Balance		+ 13.2	+ 7.5	+ 1.5	+ 4	+ 130	+ 194

10.6 Discussion

The model farm builds the basis for a farm family of 4-6 members. Annual economical return of 98,167 SL Rs meets median rural household (4.2 people) income of 96,144 SL Rs per year with 1.9 income receivers (Department of Census & Statistics, 2002 c). Systematic adoption of the organic smallholder model farm becomes financially viable after three years. A social-economic-ecological comparison of three different farming systems (traditional, organic, chemical / conventional) in Asia, including Sri Lanka, carried out under the patronage of IFOAM also revealed, that a systematic conversion of smallholder lands, if they were integrated with livestock, become financially viable two to three years after conversion, especially in marginal tea lands of Sri Lanka (Vaheesan, 2002).

Apart from high labour requirement and initial investments, production costs are low. Workload is enough to occupy two people with peak season times for part time employment of additional family members. Various skills are demanded by the farmer family for crop cultivation, animal rearing and maintenance of a biogas plant. Interestingly, for a majority of Singhalese TSH situated in the mid country plucking of tea is considered to be an unskilled type of work that is traditionally done by female Indian Tamils. Also for other maintenance of tea like pruning, weeding and fertilisation Tamil workers are being hired. McConell 1992 states: “Paradoxically, although most of these farms have a large surplus of family labour, hired labour is by far the largest cost item accounting for 87.2 % of all costs.” Since more than 50 % of the investigated organic farmer group (Part II) hired outside labour for plucking and maintenance of tea part of the agricultural income generated got lost even though family labour might have been available. This situation calls for a change in attitude towards maintenance work of tea. Lack of reputation already caused labour shortages especially in low elevation areas and has been addressed too, by responsible institutions.

Sri Lanka is not self sufficient in its food crop production and malnutrition remains a growing concern. Therefore the integration of multipurpose trees in home gardens plays a vital role for food security. Presently several species are under utilised. Organized growing under village extent and value addition using latest technologies for domestic and international markets improve availability of food and also create employment opportunities for rural youth.

For better economical return farmers can intensify specific crop production in co-operation with the farmers' group and leading organisations. At the moment demand for certain organic spices like vanilla, cinnamon, cardamom, nutmeg, pepper and cloves is higher than supply. Establishment of vanilla orchards e.g. takes time and special knowledge in particular about pollination. Manufacturing and marketing small quantities is inefficient. Too many farmers cultivating the same product can bring prices down. So, proper planning, market knowledge and group arrangements are necessary to guarantee quantities, organize a variety of products and investigate in processing facilities. At the TSHDA Soriyagoda experimental station 240 betel nut palms were planted in the drains of a 1 acre (0.41 ha) tea plot generating an additional income of 21,600 Rupees per year (Someratne, 1999 pers. communication). With a farm gate price of SL Rs 262 per kg integration of pepper vines growing on betel nut palms or gliricidia trees as a supporter brings further income of 12,576 SL Rs (CBS, 1998 a).

With the rapid depletion of forest resources in Sri Lanka due to indiscriminate cutting of trees for agriculture, industry and fuelwood needs, the availability of this traditional important energy source has become scarce. Proper use of a biogas plant has the potential to reduce the need for firewood (3.5 t of wood per household and year, Stoer 1995), increase soil fertility, improve the sanitary situation and reduce the workload. Establishment of a drainage system for easy application of liquid manure is one essential advantage of this model, saving time and energy for manure distribution. In an optimum set up drains run downhill at a slight angle (about 2 %) and can be closed off from the main canal for controlled and even distribution of arranged sections. Direct integration of other crops like betelnut and pepper within the tea stand also profit from bioslurry application.

Animal husbandry is a major component to maintain and improve soil fertility. Lack of fodder material during the dry season is one of the main limiting factors for adoption of animal husbandry. Small scale dairy farming is being supported by government projects and non government organisations (NGOs) in order to improve the household income, nutritional diet (self sufficiency) and soil fertility. But a study regarding the crop-livestock integration in Uva-Province of Sri Lanka concluded, that “the predominant problems of the rural population, the increasing land scarcity and the growing rate of unemployment can only slightly be mitigated through animal production” considering economic, socio-cultural and ecological limitations (SLE, 1993). Grazing on road sites and common property land is very common but especially for cows at risk on steep sloping hillsides and during hot and sunny days. Further it is not in line with proper watershed management implementing a risk of overgrazing and erosion. Hochegger (1998) documented 24 species used as fodder in the wet and intermediate zones of the Central Province. During the rainy season the farmers do not have severe problems with the collection of fodder as there is sufficient grass available, whereas in the dry season leaves from trees have to replace grass almost completely. In this situation a diverse cultivation system including SALT hedges (Fleddermann, 1992) and fodder grass has the potential to contribute significantly to the fodder requirement of the smallholder dairy farmer. This immediate benefit can enhance farmer’s acceptance next to the long-term effect of soil fertility improvement. Establishment of fodder grasses at the model farm involves fertilization with bioslurry and irrigation during the dry season.

Limitations

Easy access to sufficient continuous water supply is one limitation for animal rearing, the efficient digestion in the biogas plant and fodder grass production. At the research site average annual precipitation of 2,400 mm is sufficient for agricultural activities. But uneven distribution, creating two dry seasons between January and May and around September, is a cause for water scarcity. Rainwater harvesting and the construction of water tanks could improve this situation.

Money for investments is another limiting factor for buying livestock or building biogas plants. Farmers saving groups have helped individuals to receive cheap loans for realizing such projects. Farmers working groups have helped each other building stables and biogas plants and exchanging knowledge and experience.

10.7 Conclusion

An intensified diverse cultivation system with organic tea as a cash crop can be economical viable and ecological sound assuming the infrastructure for processing and marketing is provided. Being part of an organic farmers group growing of additional cash crops of organic quality has to be properly planned including available plant species inventory, farmers knowledge and market studies. In villages with complete organic production specialization and team work can be efficient. Under village circumstances a large biogas plant with a central stable and specialized animal caretakers can be thought of. Intensification of vanilla growing including seminars on pollination is recommended. Acting as a uniform and reliable group under the infrastructure and guidance of a serious organization is a precondition for successful development of this smallholder production system.

11 General discussion

Ancient cultivation systems like rice terraces in Leyte, shifting cultivation and forest gardens (Latin America, Sri Lanka) have proved their potential of sustainability over generations. To feed a growing world population production systems have changed and output increased. "When land is the limiting factor, a major production objective is to maintain or increase land quality, e.g. by maintaining or increasing soil organic matter levels for assured food production in the long run, and to increase total production per unit land" (Schiere et al., 2002). This intensification happened at the end of the 18th century in Europe when the traditional fallow period was taken for the cultivation of legumes, potatoes and roots and manure was applied to the leaf crops. With respect to soil fertility, yield levels, pest and disease management a system of changing crops was propagated by Thaer (1752 – 1828). This historical development can be seen as the successful foundation for intensive agricultural production and is applicable in modified forms throughout the world (Diercks, 1986). But the socio-economic framework of industrialisation has forced agricultural production into a high degree of rationalization and specialization. Success of modern agricultural production through high inputs of chemical fertilizer, pesticides, high yielding and genetically modified varieties is imperfect, implementing a restriction of our food basis to a limited number of plant species (Sauerborn, 2002). Yield potential of these high input agricultural systems is only reached under optimum conditions. Studying yields of major staple food crops in different countries of the world shows high differences in productivity among the countries and with regards to the average world yield. For tea (*Camellia sinensis*) as an important beverage, yield of 4,000 kg ha^{-1} year^{-1} made tea from clonal varieties has been reported by Fuchs (1989) for Sri Lanka. While average world production for 2002 was given with 1,125 kg ha^{-1} year^{-1} made tea, China as one of the major tea producers only reached an average yield of 619 kg ha^{-1} year^{-1} made tea (Tea Board India, 2002). In his elaborate study about tea environments and yield in Sri Lanka Fuchs (1989) pointed out, that in terms of economy the extremely high productivity of very young clonal tea bushes is highly satisfactory but the decrease in productivity already starts a few years after replanting and sharply increases with the advancing years of the bushes and lack of necessary inputs or adverse environmental conditions. Where as seedling tea bushes have comparatively lower yields but even the old plants still show a satisfactory production under marginal conditions. In dealing with a perennial crop, cultivation measures have to be location specific and strongly evaluated by their future impact considering social, economical and ecological factors. Next to breeding high yielding varieties much more attention should be drawn to improve existing cultivation systems in order to reach location specific yield potentials and maintain biodiversity to meet the daily required balance of food types (Sauerborn, 2002). Important studies by Crucefix (1998), Parrott & Marsden (2002) and Pretty et al. (2003) demonstrated the positive impact of organic agriculture on agricultural production, food production per household, local economy and key socio-economic parameters by presenting data from case studies of many different countries.

Smallholder tea production plays a significant role in China, Kenya and Sri Lanka (Betz, 1993). Reported low average yield levels for the tea smallholder sector are not directly comparable with the estate sector since many smallholders are involved in the cultivation of other crops, not fulfilling the recommended tea plant density per hectare. Where as tea smallholders concentrating on tea production like in lowland districts of Sri Lanka had a yield average above the country level of 1,641 kg ha^{-1} $year^{-1}$ in 2002 (Tea Board India, 2002). Interestingly, calculated average yield levels on a per plant basis of organic TSHs are comparable with conventional TSHs. Comparable coffee yields per plant were also observed for multistrata organic versus conventional coffee farms in Costa Rica (Lyngbæk et al., 2001). In their study “The real green revolution” Parrott & Marsden (2002) included a compilation of case studies of organic farms from many different countries which show increases in yield, improved soil quality and reduction of pests and diseases for crops like cotton (Egypt, India), sugarcane (India), maize (Brasil) and sorghum and millet (Burkina Faso) under organic management. Next to improved performance of cash crops raising farmer’s income, enhanced biodiversity increases productivity per area creating jobs and improving local food security (Pretty et al., 2003).

Next to precipitation soil fertility is a main limiting factor for crop production. The aim of nutrient management within organic farming systems is to work within a closed system using organic materials. Organic manuring is often restricted due to the unavailability of recommended materials in adequate quantities. Experiments by Ouédraogo et al. (2001) showed that sorghum yield tripled with compost application of 10 Mg ha^{-1} and mitigated negative effects of a delay in sowing in Burkina Faso. However, lack of equipment and adequate organic material were major constraints mentioned by the farmers for the adoption of compost technology. Hoffmann et al. (2001) studied an indigenous system of soil fertility management in the Zamfara Forest Reserve of northwest Nigeria, where farmers combine crop planting pattern and the application of organic and mineral fertilizer in an effective way to maintain the fertility of their soils. Here also, major problems mentioned by the farmers were soil fertility and scarcity of organic and inorganic fertilizer. So, one of the biggest challenges in the tropics is to develop organic matter technologies which are adopted by the farmers. Snapp et al. (1998) evaluated (1) the effects of residue quality; (2) the role of deep rooting systems, and (3) tradeoffs between legumes grown for grain versus soil regeneration as organic matter technologies for integrated nutrient management in smallholder cropping systems of southern Africa. They concluded that the promotion of grain and tree legumes with deep root systems was one of the most effective ways to improve nutrient recycling on-farm in S. Africa. In search of organic nutrient sources a great number of effective measures and techniques have been invented and tested for their suitability. Adoption greatly depends on local circumstances and implemented side effects. Activities within waste management systems, such as energy and material recovery, can lead to indirect environmental impacts that occur outside of waste management systems. Decomposition of animal waste under anaerobic conditions produces CH_4, CO_2, N_2O and soil organic matters (SOMs). These gases are also known as greenhouse gases (GHG) recognized for their global warming potential. Ruminant livestock can produce 250 to 500 L of methane per day, heavily depending on the feeding habits (Johnson & Johnson, 1995). Production of biogas from a 4 m^3 biogas plant is given with 1 m^3 day^{-1} (Stoer, 1995) consisting of 65 % CH_4, 22 % CO_2 and 0.03 % N_2O under monthly average temperatures of 20-25 °C (Su et al., 2003). In order to minimize GHG emissions it is essential to properly employ methane as a fuel from anaerobic wastewater treatment systems. Bhattacharya et al. (1997) concluded that only small fractions of the amounts of animal wastes that are potentially recoverable for biogas production are recovered. Meaning that the potential of biogas to replace fossil fuels for mitigation of GHG emissions is significant.

12 Summary

In Sri Lanka the agricultural structure of smallholder production has changed with population growth and land reforms. In former days a farm family could life from the production of their home garden through subsistence farming and barter economy. Additional income was achieved by selling surplus products like spices on the local markets. Today living standards and life style have changed and monetary needs for housing, schooling, electricity, telephone, household goods and transport facilities are much higher. Many smallholders are involved in single cash crop cultivation and outside employment for income generation. Lack of available arable land and infrastructure are main reasons for the limited economical success of many smallholders in Sri Lanka. This study investigated whether the formation of farmer groups under patronage of an organisation and private company next to adoption of organic agriculture practices can be recommended as an economical viable and ecological sound alternative. Hence a survey was conducted in Kandy District of Sri Lanka, as well as field and laboratory experiments carried out in co-operation with the Tea Research Institute, Talawakele and the Post Graduate Institute of Agriculture, University of Peradeniya.

Data from 529 organic tea smallholders (TSHs) were collected between 1997 and 1999. From the findings the study describes the present situation of organic TSHs production systems in Kandy District, Sri Lanka organised under Bio Foods Ltd. Organic Tea and Spices and Gami Seva Sevana (GSS) a Non Governmental Organisation (NGO). Methods applied include taking of farm inventory, questionnaires and semi-structured interviews with farmers and key respondents, drawing of land sketches, evaluation of data records from respective organisations and engagement in post harvest processes (extension, processing, packing, export, inspection).

Results showed that 92 % of the organic tea smallholders cultivated plots on former tea plantation land with an average size of 0.4 ha and a given agricultural structure. Mainly seedling tea was grown on steep slopes and 70 % of the farmers cultivated less than 1000 bushes. In depth studies at 23 TSH sites revealed 77 plant species of economical value. For about 35 % of the organic holdings animal production served as an additional source of income (milk, meat, drought power). Out of the whole calculated farm income 42 % was generated from tea, 24 % from fruit and spices and 16 % from treacle, nuts, coffee and cacao. If dairy cows are present 18 % of the farm income is generated from milk sales. Through contract farming with experienced organisations, as well as professional processing and marketing of tea as an exclusive organic product, the farmers obtained premium green leaf prices and a stable income. The stable income served as an incentive to improve the performance of agricultural standards. Here the support of a dedicated extension service brings beneficial inputs. Tea production of the investigated organic TSHs rose by 16 % from 1998 until 2000. Including the marketing of organic fruit and spices there is a high potential for resource poor organic tea smallholders to overcome ecological and economical limitations.

Next to the evaluation of the production system, maintaining and improving soil fertility is a major issue for the level of production. Organic manuring is often restricted due to the unavailability of recommended organic materials in adequate quantities. Preparation of compost is time consuming and work intensive and without animal faeces less effective and accepted. The dissemination of biogas plants in the project area gave the incentive to carry out investigations regarding the use of bioslurry for organic tea cultivation. Hence field experiments were conducted to evaluate the effect of organic amendments, namely bioslurry, goat compost and bokashi, on the establishment, growth and yield of tea (*Camellia sinensis)*. Goat compost was made out of goat manure and the remaining materials from the roughage feed given to the goats. Bokashi is a special fermented fertilizer made according to a Japanese recipe (Ahmed, 1995) using soil (50 %), chicken manure (30 %), pressed rape seed oil cake (15 %), rice bran (2-3 %), charcoal (1 %) and boiled livestock bone (about 1 %). Cow and pig excreta passing through a biogas plant, undergoing an anaerobe digestion process for about 70 days are referred to as bioslurry. These three organic amendments at a rate of 3/48/63 t ha^{-1} $year^{-1}$ DM were chosen for planting a new tea field. Growth assessments indicated higher plant growth rates of the bioslurry plots when compared with compost treatments. Nutrient balance of a mature tea field partly manured with bioslurry at a rate of 10 l $plant^{-1}$ $year^{-1}$ and 12 kg compost respectively showed that bioslurry in combination with mana grass mulch has the potential to add sufficient amounts of nutrients to the soil in order to replace nutrient loss through harvest material. However considering nutrient uptake for plant growth and volatile losses, especially of ammonia, bioslurry application has to be increased and a combination with compost application is recommended.

Since organic agriculture plays a key role in maintaining soil fertility and biodiversity, protecting the environment and keeping social standards a model farm with organic tea cultivation as a cash crop was designed. Research findings and personal experiences were taken as a basis for a location specific model of plant production including fodder cultivation, SALT (Sloping Agriculture Land Techniques) hedges, animal husbandry and operation of a $4m^3$ biogas plant. As main cash crops about 3,000 tea plants are cultivated in a mixed cropping system with 50 pepper vines (*Piper nigrum*), 56 betel nut palms (*Areca catechu*) and 100 gliricidia trees (*Gliricidia sepium*). Remaining 148 plants are grown around the tea field, along the border and surrounding the house. From an average plant species richness of 41 per 0.47 ha with a total of 3,354 plants a monetary value of about 78,000 SL Rs (1998: 1,054 €) per year from plant production was calculated. The total monetary value of cow and goat milk yield added up to approximately 20,000 SL Rs (1998: 270 €) per year. Generated income from farming covers the costs of production. Initial investments for animals, stables and set up of a biogas plant have to be covered by savings and loans. Systematic conversion of smallholder lands with livestock integration becomes financially viable after three years.

Specialisation next to diversification ensures income generation and biodiversity as well as an improved nutritional diet for the farm family. Integration of SALT hedges for erosion control also serves as fodder and mulch material. Cultivation of fodder grass assures continuous fodder supply and cuts down walking hours for carrying fodder material from further distances. Proper use of the biogas plant reduces the need for firewood, increases soil fertility through the distribution of bioslurry and improves the sanitary situation.

In spite of favourable climatic and soil conditions, Sri Lanka is not self sufficient in its food crop production. Population growth, land fragmentation, ownership patterns, lack of infrastructure and erosion are main factors for low productivity causing land migration because of high rural poverty rates. Alternatives and different objectives of production are required for the survival of the existing population, to solve shortages of food and feed biomass and threats to sustainability. Organic practices use cheap and locally available resources. The productivity of agricultural systems can be improved in the absence of factors like mineral fertilizer, synthetic pesticides, improved seeds and access to credits over which farmers have little control. Organic agriculture techniques replace external inputs by ecological services and farmer’s management skills. This study investigated the status quo of an organic farming system. The interpretation of the survey results led to the design of a location specific model farm, where production goals were matched as close as possible to the resource base.

13 Zusammenfassung

Die ökologische Bewegung in Sri Lanka begann in den frühen 80er Jahren ausgelöst durch den Kontakt von Nicht Regierungs Organisationen mit Vertretern des ökologischen Landbaus aus den Philippinen. 1987 wurde der erste Teegarten nach den Richtlinien des ökologischen Landbaus zertifiziert. Heute sind mehr als 15 Projekte mit dem Anbau, der Verarbeitung und dem Handel von über 20 Kulturen aus kontrolliert ökologischem Landbau beschäftigt. 1998 wurde in Sri Lanka eine Fläche von ca. 3.800 ha nach Richtlinien des ökologischen Landbaus bewirtschaftet. Die wichtigsten ökologisch angebauten Kulturen sind Tee, Kokosnüsse, Cashewnüsse, Gewürze (Zimt, Kardamon, Muskatnuß, Pfeffer, Nelken, Ingwer), Früchte (Mango, Papaya, Passionsfrucht) und Kräuter (Citronella, Zitronengrass). Der größte Anteil der Produktion wird nach Europa, Japan und Australien exportiert.

Zertifiziert ökologischer Anbau in Sri Lanka, 1998

Produkt	Kleinbauern (Anzahl)	Plantagen (Anzahl)	Fläche (ha)	Produktion (t)	Ernte (kg ha^{-1})	Exportiert (t)
Schwarztee	522	6	1140	399.7	130-900	261.7
Grüner Tee *	414	2	490	60.0	350-700	42.0
Cashewnüsse	>140	0	142	57.0	440	48.0
Kokosraspeln	>14	0	307	133.3	500 Nüsse	73.3
Gewürze	Ca. 1000	6	300	25.0	-	15.0
Kräuter	Ca. 1000	4	30	10.0	-	5.0
Früchte	Ca. 1000	4	1814	84.0	-	30.0

Source: Williges & Sauerborn, 2000

*Grüner Tee wird saisonal von derselben Fläche wie Schwarztee geerntet

In Sri Lanka hat sich die landwirtschaftliche Struktur kleinbäuerlicher Produktion mit wachsender Bevölkerungszahl und durch Landreformen sehr verändert. Früher konnte eine Kleinbauernfamilie durch Subsistenz- und Tauschwirtschaft von der Produktion ihres Hausgartens leben. Zusätzliches Einkommen wurde durch den Verkauf von Überschüssen wie z.B. Gewürzen auf den lokalen Märkten erwirtschaftet. Heute sind aufgrund veränderter Lebensgewohnheiten und Ansprüche die Ausgaben für Wohnung, Schule, Elektrizität, Telefon, Haushalt und Transport gestiegen. Viele Kleinbauern haben sich auf den Anbau einer verkaufsfähigen Marktfrucht konzentriert und erwirtschaften zusätzliches Einkommen durch eine Erwerbstätigkeit außerhalb ihres Betriebes. Mangel an landwirtschaftlicher Fläche und schlechte Infrastruktur sind die Hauptgründe für den begrenzten ökonomischen Erfolg vieler Kleinbauern

in Sri Lanka. Die vorgelegte Arbeit untersuchte, ob die Bildung von Kleinbauerngruppen unter Leitung einer lokalen Organisation und einer privaten Firma sowie die Umstellung auf ökologischen Anbau als ökonomisch rentable und ökologisch nachhaltige Alternative empfohlen werden kann. Dafür wurde sowohl eine Erhebung im Bezirk Kandy in Sri Lanka durchgeführt als auch experimentelle Versuche im Feld und Labor in Kooperation mit dem Teeforschungsinstitut in Talawakele und der landwirtschaftlichen Fakultät der Universität Peradeniya.
Daten von 529 Kleinbauern die Tee (*Camellia sinensis*) nach Prinzipien des ökologischen Anbaus kultivieren wurden zwischen 1997 und 1999 gesammelt. Die Ergebnisse bilden die Grundlage für die Beschreibung der derzeitigen Situation des kleinbäuerlichen ökologischen Teeanbausystems im Bezirk Kandy, unter Leitung der Firma Bio Foods Pvt. Ltd. Organic Tea and Spices und der Nicht-Regierungs-Organisation (NRO) Gami Seva Sevana (GSS). Folgende Methoden wurden zur Datenerhebung angewandt: Hofinventur, Fragebögen, halbstrukturierte Interviews mit Bauern und Vertretern der ökologischen Landbaubewegung in Sri Lanka, Skizzen von Betriebs- und Gartenplänen, Auswertung der erhobenen Betriebsdaten von Bio Foods und GSS sowie beobachtende Teilnahme an Teeverarbeitung und Teeverpackung, Beratung, Export und Inspektion.

Die Ergebnisse zeigten dass 92 % der kleinbäuerlich ökologisch wirtschaftenden Teeanbauer 0.4 ha große Parzellen von früheren unrentabel gewordenen Teeplantagen mit einer vorgegebenen landwirtschaftlichen Struktur bewirtschafteten. Der Teebestand an den steilen Hängen war überwiegend aus Sämlingen gezogen und mehr als 50 Jahre alt. Bei 70 % der Bauern wurden weniger als 1.000 kultivierte Teebüsche gezählt. Die Aufnahme des Pflanzeninventars auf der Fläche von 23 Teekleinbauern ergab 77 genutzte und ökonomisch bedeutsame Pflanzenarten. Bei ungefähr 35 % der ökologisch wirtschaftenden Kleinbauern diente die Tierhaltung als zusätzliche Einkommensquelle (Verkauf von Milch, Fleisch und Zugkraft). Das errechnete Farmeinkommen setzt sich zusammen aus dem Teeanbau (42 %), dem Verkauf von Früchten und Gewürzen (24 %) und dem Verkauf von Palmsirup, Nüssen, Kaffee und Kakao (16 %). Wenn Milchkühe gehalten wurden entstanden 18 % des Einkommens aus dem Milchverkauf. Aufgrund des Vertragsanbaus sowie der professionellen Verarbeitung und Vermarktung von Biotee durch Bio Foods und GSS, erhielten die Teeanbauer einen fest vereinbarten höheren Preis für ihr grünes Blatt und erwirtschafteten damit ein stabiles Einkommen. Das stabile Einkommen diente als Anreiz das landwirtschaftliche Produktionssystem zu verbessern. Bei der Verbesserung des landwirtschaftlichen Produktionssystems wurden die Bauern von einem engagierten Beratungsteam unterstützt. Die Teeproduktion der untersuchten ökologisch wirtschaftenden Kleinbauern stieg um 16 % von 1998 bis 2000. Unter Berücksichtigung der Vermarktung von ökologisch angebautem Obst, Gemüse und Gewürzen hat der kleinbäuerliche ökologische Teeanbau das Potential trotz knapper Ressourcen ökonomisch rentabel und umweltschonend zu sein.

Die Evaluierung des Produktionssystems gab Aufschluss über die Breite der Produktionsmöglichkeiten. Die Erhaltung und Verbesserung der Bodenfruchtbarkeit ist von wesentlicher Bedeutung für die Intensität der Produktion. Aufgrund eines Mangels an geeigneten organischen Materialien in ausreichender Menge ist die organische Düngung oft nur eingeschränkt möglich. Die Herstellung von Kompost ist zeitaufwendig und arbeitsintensiv und wird von Bauern ohne tierischen Dung ungern akzeptiert und als wenig effektiv bezeichnet. Die Verbreitung von Biogasanlagen im Projektgebiet war ausschlaggebend für die Untersuchungen zur Anwendung von Faulschlamm aus Biogasanlagen zur Düngung im ökologischen Teeanbau.
Aufgrund seines Nährstoffgehaltes und humusformender Eigenschaften wurde Faulschlamm traditionell schon als wertvoller organischer Dünger verwendet. Hauptgründe für den Bau einer Biogasanlage liegen in der Produktion von Methan als Energieträger und Faulschlamm zur Düngung. Gutterer & Sasse (1993) belegen in einer umfangreichen Studie über Biogasanlagen das 90 % der untersuchten 109 Bauern aus 14 Ländern den Hauptnutzen in der Gasproduktion sehen. Die Art und Intensität der Verwendung von Faulschlamm als Flüssigdünger hängt stark von der landwirtschaftlichen Tradition, individuellen Interessen, Produktionsstandort und Exposition, Transportmöglichkeiten und nicht zuletzt der lokalen Agrarberatung ab.
Im Bereich der Tropen und Subtropen wurden positive Wirkungen auf die Bodenfruchtbarkeit und das Pflanzenwachstum nach Faulschlammdüngung für den Gemüseanbau (Hinterberger, 1990) und die Kulturen Zuckerrohr (Tiwari et al., 1997) und Reis (Ojha & Talukdar, 2000) beschrieben. Eine Studie von Chen, 1997 stellt dar wie eine Biogasanlage als Hauptverbindungsstück zwischen Obstbau (*Citrus grandis*) und Tierproduktion einen wesentlichen Beitrag zur ländlichen Energiversorgung leistet. Die Literaturrecherche ergab keine wissenschaftlichen Hinweise zur Nutzung von Faulschlamm aus Biogasanlagen im Teeanbau.

Somit wurden Feldversuche durchgeführt um den Einfluss organischer Dünger, namentlich Faulschlamm, Ziegenkompost und Bokashi, auf die Etablierung, das Wachstum und den Ertrag von Teepflanzen zu untersuchen. Ziegenkompost wurde aus Ziegendung und pflanzlichen Abfällen die z.B. auch bei der Fütterung anfallen hergestellt. Bokashi ist ein fermentierter Dünger, welcher nach einem japanischen Rezept (Ahmed, 1995) hergestellt wurde und aus 50 % Erde, 30 % Hühnerdung, 15 % gepresstem Rapsölkuchen, 2-3 % Reiskleie, 1 % Asche und 1 % gekochtem Knochenmehl besteht. Faulschlamm entsteht, wenn Kuh und Schweinedung innerhalb von 70 Tagen unter anaeroben Bedingungen eine Biogasanlage passieren. In einem Feldversuch wurden Teepflanzen mit diesen drei organischen Düngern mit einer Aufwandmenge von 3/48/63 t ha^{-1} $Jahr^{-1}$ Trockenmasse gepflanzt. Wachstumsmessungen deuteten auf bessere Wachstumsraten für die Faulschlammvariante im Vergleich zu den Kompostvarianten. Die Nährstoffbilanzierung eines achtjährigen Teefeldes, welches zu gleichen Teilen mit 10 l Faulschlamm pro Pflanze und 12 kg Kompost pro Pflanze gedüngt wurde ergab, das Faulschlammdüngung in Kombination mit Managras Mulch den Nährstoffverlust durch die Ernte des Teeblattes wieder ausgleichen kann. Berücksichtigt man aber die Nährstoffverluste durch

Pflanzenwachstum und Verflüchtigung besonders von Ammonium, dann wird eine Erhöhung der Faulschlammgaben in Kombination mit Kompostapplikation empfohlen.

Da der ökologische Landbau eine Schlüsselrolle bei der Erhaltung der Bodenfruchtbarkeit und Biodiversität spielt, und darüber hinaus Umweltschutz und soziale Standards berücksichtigt, wurde eine ökologische Modellfarm mit dem Anbau von Tee als Marktfrucht entwickelt. Aus Untersuchungsergebnissen und persönlichen Erfahrungen wurde ein lokal spezifisches Modell entwickelt, welches Tierhaltung, Futterproduktion, SALT (Sloping Agriculture Land Technique) Hecken und die Nutzung einer $4m^3$ Biogasanlage beinhaltet. Als Marktfrüchte werden 3.000 Teepflanzen in Mischkultur mit 50 Pfefferranken (*Piper nigrum*), 56 Betelnusspalmen (*Areca catechu*) und 100 Gliricidia Bäumen (*Gliricidia sepium*) angebaut. Weitere 148 Pflanzen wachsen um das Teefeld herum, entlang der Feldgrenze und um das Haus herum. Der durchschnittliche Pflanzenreichtum von 41 Arten pro 0,47 ha Fläche mit einer Gesamtzahl von 3.354 Pflanzen, entspricht einem Wirtschaftswert von ca. 78.000 SL Rs (1998: 1054 €) pro Jahr. Die Erträge aus Kuh und Ziegenmilchverkauf belaufen sich auf ca. 20.000 Sl Rs (1998: 270 €) pro Jahr. Das mit der landwirtschaftlichen Produktion erzeugte Einkommen deckt die Produktionskosten. Notwendige Investitionen in Tiere, Ställe und den Bau einer Biogasanlage müssen über erspartes oder Schulden finanziert werden. Die systematische Umstellung von kleinbäuerlicher Produktion auf ökologischen Anbau mit der Integration von Tierhaltung trägt sich finanziell nach 3 Jahren.

Spezialisation auf den ökologischen Landbau mit dem Schwerpunkt des Anbaus von Tee und Vanille z.B. in einem diversifizierten Anbausystem sichert Einkommen und biologische Vielfalt und verbessert die Nahrungsgrundlage für die Bauernfamilie. Die Integration von Hecken als Erosionsschutz (Sloping Agriculture Land Technique) dient gleichzeitig als Futter und Mulchmaterial. Der Anbau von Futtergras sichert die kontinuierliche Versorgung der Tiere und verringert den Zeitaufwand der Futtersuche und des Transportes. Die ordnungsgemäße Nutzung der Biogasanlage reduziert den Feuerholzbedarf, erhöht die Bodenfruchtbarkeit durch die Faulschlammnutzung und verbessert die sanitäre Situation.

Trotz günstiger klimatischer Bedingungen und guter Böden kann Sri Lanka nicht den Eigenbedarf an Hauptnahrungsmitteln durch die landwirtschaftliche Produktion decken. Bevölkerungswachstum, Landteilung, Besitzverhältnisse, mangelnde Infrastruktur und Erosion bilden die Hauptfaktoren für die geringe Produktivität in der Landwirtschaft und führen zur Landflucht aufgrund von steigender Armut in ländlichen Regionen. Alternativen und neue Ansätze für die Produktion werden benötigt um das Einkommen der Bevölkerung zu sichern, Engpässe bei Nahrungsmitteln, Futter und Biomasse zu überwinden und nachhaltiger zu wirtschaften. Diese Untersuchung beschreibt den status quo des kleinbäuerlichen ökologischen Teeanbaus in Sri Lanka. Die Interpretation der Untersuchungsergebnisse führte zum Entwurf einer lokal angepassten Modellfarm, in der die Produktionsziele den vor Ort vorhandenen Ressourcen angepasst wurden.

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Eidesstattliche Erklärung

Hiermit versichere ich, Ute Williges, an Eides Statt, daß ich diese Arbeit selbstständig und ohne fremde Hilfe verfaßt und keine anderen als die angegebenen Hilfsmittel benutzt habe. Diese Erklärung schließt auch alle Zeichnungen, bildlichen Darstellungen und dergleichen mit ein. Diejenigen Stellen der Arbeit, die dem Wortlaut oder dem Sinn nach anderen Werken entnommen sind, sind in jedem Fall unter der Angabe der Quelle der Entlehnung kenntlich gemacht. Gleichzeitig versichere ich, dass diese Arbeit noch nicht veröffentlicht oder in einem anderen Prüfungsverfahren als Prüfungsleistung vorgelegt worden ist.

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7/2002 – 2004	Maternity leave and continuation of scientific work
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1996 – 1997	Representative of the academic staff at the Scientific Centre for the Tropics (WZT) at the Justus-Liebig-University (JLU) of Giessen, Germany
1995 – 1997	Scientific assistant at the faculty for plant production and breeding in the tropics and subtropics, JLU Gießen

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1988	„American High-School-Diploma“ in New Jersey, USA
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6 – 8/1992	Apprenticeship at the Projet-Agro-Ecologie (PAE) Ouahigouya in Burkina Faso, West-Africa in the fields of resource management, animal production and environmental protection
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7 – 9/1991	Apprenticeship at a bio-dynamic vegetable farm cultivating with percheron horses in California, USA
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Foreign travels

12/1997 – 10/1999	Sri Lanka
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