Handbook of Organic Crop Production in Sikkim

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Government of Sikkim
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FOREWORD

Sikkim, the 22nd state of India, lies in the Eastern Himalayas between 27° to 28° North latitude and 88° to 89° East longitude. To its North lies the vast stretch of Tibetan Plateau with Nepal in the West, Bhutan and Chumbi Valley of Tibet in the East and Darjeeling District of West Bengal in the South. About 80 per cent of the people are directly or indirectly dependent on the scarce land resource for their livelihood. Rural population constitutes 74.85 per cent and density of population is 86 persons/sq km. Nestled in the Himalayas, the economy of Sikkim is linked with agriculture that serves as the foundation of livelihood and economic security to the substantial native population. Historically, agriculture in Sikkim has been low external input driven and the majority of the farming in Sikkim could be termed 'near organic' or 'organic by local practices' and we capitalized on this advantage to declare the state as 'organic' in 2003. Thereafter, we have taken measured but series of steps towards achieving full conversion by 2015.

Increasing awareness on food and health security related issues in Sikkim amongst the public, planners and policy makers is of crucial importance especially in relation to organic farming, conservation of biodiversity and sustainable management of natural resources. This will be fundamental to meet the future food, health, environmental and livelihood security of the state. We have chosen to tread the untrodden path of going organic in the context of widespread use of chemical fertilizers and pesticides all around. That means, we have no model to follow and no example to emulate. In that sense, we are the innovator, the pathfinders and the first State in the Country to present organic farming practices.

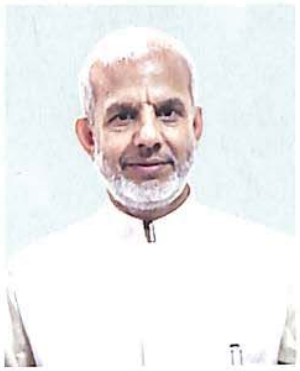
Political leaders the world over and the many agricultural scientists have profusely appreciated our initiative to go organic. Sikkim has been a talking point both nationally and globally and we must move forward to harness this goodwill and support emanating from cross-section of leaders and people. I am happy that at this vital juncture the book titled "Handbook of Organic Crop Production in Sikkim" is being published by the Sikkim Organic Mission under research based technological backup of ICAR Research Complex for NEH Region, Sikkim Centre, Tadong, Gangtok.

This book is a major step forward to take organic farming to the next level with indigenous research findings and compiled information that are essential to address the current and futuristic needs for sustainable organic agriculture and horticulture production systems in Sikkim. The book encapsulates considerable information on organic farming and will add new dimensions to the research in organic agriculture. The book touches upon areas that are envisaged to meet tomorrows' requirements and offers avenues for those willing to venture further as practicing organic farmers. It also provides keen insights into the various aspects of the farming practices that will address the basic requirements of organic farming in high rainfall hilly areas. The readers will note that the chapters are of immense value and include wide diversity of crops grown in Sikkim Himalayas.

I am sure that researchers, planners, academicians, industrialists, policy makers, NGOs, farmers' and extension functionaries will find the book valuable, practical and functional. Let me once again call upon my fellow citizens to work in unison with the State Government officials so that the trust and confidence reposed on us by the countrymen is fully reciprocated and fulfilled.

With best wishes,

(Pawan Chamling)



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MESSAGE

Mountain farming systems all over the world are most vulnerable to the adverse impacts of climate change. Sikkim, being located in the Himalayan range, is also being strongly affected by this global phenomenon. These emerging circumstances have thrown before us a major challenge of adapting to this change by opting for a sustainable farming system. Conscious efforts have to be made to balance sustainable economic production while addressing the issue of food security. Our fragile ecosystem and depleting natural resources must be strategically managed to extract optimum benefits without causing any damage to the environmental and ecological stability. Of late, the world community has also realized the detrimental effects of conventional farming on human health and the importance of organic farming in promoting a healthier planet. In light of the above factors, the political leadership has taken a positive initiative to adopt organic farming in Sikkim for addressing the environmental issues and human health concerns without compromising on food production.

The State Government has taken this novel initiative with the target of achieving complete organic status by the year 2015. The Hon'ble Chief Minister, Shri Pawan Chamling, must be lauded for his vision and foresight which has insured that this organic dream becomes a reality. The adoption of organic policy has introduced a new paradigm in our agricultural production system which decreases the dependency on harmful off-farm inputs.

The challenge now lies in sustaining this organic movement and calls for a proactive participation from all stakeholders especially the farming community. It is, therefore, time for integrating knowledge from the scientific community with local resources and time-tested traditional knowledge to develop modern organic production technologies for optimizing the productivity. At present, organic crop production system is the best alternative amongst all other considerations for sustainable farming.

I am happy to learn that a book on organic crop production is coming out at this crucial juncture when resource materials are the need of the hour. This book titled 'Handbook of Organic Crop Production in Sikkim' is being published by Sikkim Organic Mission with the support of ICAR Research Complex for NEH Region, Sikkim Centre. This book will prove to be of immense help to agriculture scientists, policy makers, academicians, state officials, extension functionaries and the farming community at large. I am certain that the publication will be a good reference material for understanding the finer nuances of organic crop production. This publication will certainly be received as a great achievement in the annals of Sikkim's organic journey.

I congratulate all those associated with the publication of this book and wish the team every success in all their future endeavours.

(Somnath Poudyal)

PREFACE

The Eastern Himalayas of India with an incredible diversity in flora and fauna constitute one of the richest regions on earth. High rainfall along with humid tropical to arctic climate and other influencing factors such as altitude, manifest tremendous differentiation of ecosystems and provide refuge to a variety of unique life forms. On the western end of the Indian side of the Eastern Himalaya lies Sikkim, one of the smallest states of India. With a total area of 7096 km^2, of which 3359 sq km (47.34 per cent) is under forest (FSI, 2011). With almost no flat land, this entirely mountainous state has altitude range from 300 to 8598 m above mean sea level (amsl). The relatively well-protected forest vegetation vary from the subtropical forests, temperate broad-leaved and coniferous forests to sub-alpine scrubs and alpine meadows.

Terraced cultivated fields interspersed with streams along with bamboo and tree groves are the traditional hill agriculture confined to elevations up to 2000 m. Elevation, climate and mountain terrain strongly influences the land use in Sikkim, especially agriculture and forestry. Barely 11 per cent of area of the total geographical area of 7,09,600 ha is under cultivation and this small landmass reveals high agricultural diversity. It is estimated that more than 60 per cent of the populace of the State is dependent on agriculture that is mainly rainfed and mixed type with around 11 per cent irrigated area. Fruits, vegetables, floriculture and spice crops, other than large cardamom constitute the majority in the livestock-driven horti-agri farming systems. The principal crops of the state are maize, rice, large cardamom, ginger and mandarin. Wheat, mustard, buckwheat, urdbean, finger millet, soybean and beans along with large array of vegetables, fruits and flowers add to the diversity of crops grown in Sikkim. Majority of the agriculture in Sikkim is still at subsistence scale especially in the case of food grains with farmers' continued preference for traditional varieties since these are well adapted to the region with superiority in quality and palatability. The domestic production is not able to meet the requirements of the state, hence, major food grains are supplemented from other states. The cultivation practices are largely traditional but the farmers are now adopting improved technologies under the organic farming system.

In order to strengthen the process of conversion to organic farming by State Organic Mission and create self sufficiency in organic production, ICAR along with state officials and other departments has taken lead to publish a "Handbook of Organic Crop Production in Sikkim". We expect that this book will be very helpful to the farmers, state officials, researchers, academicians, industrialists, policy makers, extension functionaries and NGOs. The book mainly focuses on research and development based organic agriculture and horticulture production technologies suitable for Sikkim hills with majority of the recommendations based on research undertaken at ICAR Research Complex for NEH Region, Sikkim Centre, Tadong, Gangtok; National Research Centre for Orchids, Pakyong, East Sikkim and Indian Cardamom Research Institute, Sikkim Unit, Tadong, Gangtok. The organic nutrient management has been developed in consultation with National Bureau for Soil Survey and Land Use Planning, Kolkata Regional Centre based on the recently completed geo-referenced soil fertility mapping of Sikkim. Multidisciplinary group of scientists have contributed to bring out this essential book. We have tried to include almost all the major crops growing in Sikkim. We are grateful to all the contributors for their dedicated efforts and submission of chapters within the time frame. The editors have made utmost efforts to eliminate errors in the text. Constructive criticism is welcome which will be thankfully acknowledged.

We extend our sincere gratitude to Sh. Pawan Chamling, Hon'ble Chief Minister of Sikkim for his vision and farsightedness; Sh. Somnath Poudyal, Hon'ble Minister, Food Security and Agriculture Development Department and Horticulture and Cash Crops Development Department, Govt. of Sikkim for his valuable support; Shri P. D. Rai, Hon'ble Member of Parliament (Lok Sabha); Dr S. Ayyappan, Secretary, DARE, Govt. of India and Director General, ICAR, New Delhi; Dr A. K. Sikka, Deputy Director General (NRM), ICAR, New Delhi; Dr K. M. Bujarbaruah, Vice Chancellor, Assam Agricultural University, Jorhat; Dr S. V. Ngachan, Director, ICAR Research Complex, Umiam, Meghalaya; Shri P. T. Bhutia, Secretary, Food Security and Agriculture Development Department (FS&ADD), Government of Sikkim; Dr Dipak Sarkar, former Director, National Bureau for Soil Survey and Land Use Planning; Dr T. H. Das, In-charge Head, Dr A. K. Sahoo, Principal Scientist, Dr S. Mukhopadhyay, Sr. Scientist, National Bureau for Soil Survey and Land Use Planning, Kolkata Regional Centre, for their technical guidance, support and encouragement. We are greatly indebted to Dr Ashish Yadav, Senior Scientist (Horticulture), ICAR Sikkim Centre for his tireless efforts in the compilation of this publication. We sincerely acknowledge the immense contribution made by the scientists of ICAR Sikkim Centre; NRC for Orchids, Pakyong, East Sikkim and ICRI, Sikkim Unit. We express deep sense of gratitude to all who provided well-timed and precious support in bringing this book in to a reality.

Editors

Dedicated to

the Land,

Culture and

Farming Community of

Sikkim

About the editors

Dr Ravikant Avasthe has held the positions of, Principal Scientist (Soils) and Joint Director of ICAR Research Complex for NEH Region, Sikkim Centre, Tadong, Gangtok since July 2013. Possessing a good academic record he joined ICAR in January 2000. Dr. Avasthe, a multi-lingual, possesses more than two decades' experience of working in the Sikkim Himalayas in various capacities and also of having served different institutes in the country. He was awarded Masters' degree from G. B. Pant University of Agriculture and Technology, Pantnagar in 1984 and subsequently obtained his Ph. D. from *alma mater* in 1990. Prior to assuming the current position at Gangtok, he was the Head of the Division of Human Resource Development and Social Sciences of Central Soil and Water Conservation Research and Training Institute, Dehradun (Uttarakhand), a premier institute of Indian Council of Agricultural Research involved in soil and water conservation and watershed management during 2011-13. He has enormous and varied experience of research, extension and capacity building in the field of soil fertility management in cereals, pulses, oilseeds and vegetables; development of organic nutrient management packages for rice, maize, buckwheat, mustard and soybean; soil acidity management and soil and water conservation; land use planning for management of agricultural resources; watershed management; collection, evaluation and conservation of potential crops, promoting their cultivation by value addition, capacity building of farmers in seed production and conservation of agro-biodiversity; spices especially large cardamom and ginger, medicinal, and aromatic plants; additionally he has structured programmes for livelihood improvement and empowerment of rural poor in very remote mountainous areas. Before moving to Dehradun, Dr. Avasthe served ICAR Research Complex for NEH Region, Sikkim Centre as Senior Scientist (Soil Science) during 2000-08 and from 2008 to 2011as Principal Scientist. His career with Indian Council of Agricultural Research began as Sr. Scientist (Soil Science) at the Directorate of Oil Palm, Eluru, West Godavari district in Andhra Pradesh in the year 2000. Initially from 1992-94 he was Scientist at ICAR Sikkim Centre and thereafter, in 1994 as Senior Programme Officer with World Wide Fund for Nature-India (WWF-India) started the biodiversity conservation initiatives and developed and implemented many biodiversity conservation projects including high altitude surveys related to biodiversity, wetlands, raising emergent issues demanding conservation attention, commencement of environmental education and awareness programmes in schools and colleges of Sikkim for WWF-India under the Biodiversity Hotspots Conservation Programme and was responsible for the establishment of WWF-India Sikkim Field Office in 1994 and worked till 1999. Declaration of Pangolakha Wildlife Sanctuary in 2000 was an outcome of the efforts of WWF-India and Forest, Environment and Wildlife Development Department, Government of Sikkim. In the initial stages of his career he served as Research Associate at the International Crops Research Institute for Semi Arid Tropics (ICRISAT), Hyderabad during 1984-87, Indian Agricultural Research Institute (IARI), Pusa, New Delhi and Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad (1991-92). He has more than 160 publications as research papers in peer reviewed national and international journals/Proceedings, books, reports, technical bulletins, manuals, book chapters *etc*. His better-half Dr Yashoda Pradhan is Additional Executive Director, Sikkim Organic Mission, Food Security and Agriculture Development Department, Government of Sikkim and has one son, Vismaiy Avasthi.

Dr Yashoda Pradhan, SAS, is Additional Director, Food Security and Agriculture Development Department, Government of Sikkim since 2011. She completed her Masters' degree from Himachal Pradesh Krishi Vishwavidyalaya, Palampur in 1985 and thereafter, received Ph. D. (Soil Science) from G. B. Pant University of Agriculture and Technology, Pantnagar in 1990. She has the unique distinction of being the first lady officer of the Department of Agriculture and also the first lady from the state of Sikkim to acquire doctorate in agricultural sciences. She was posted as Additional Executive Director, Sikkim Organic Mission in 2013. Earlier, she was Additional Director (Agriculture Census and PME) during 2011-13 and was promoted to the post of Joint Director (Agriculture Census and PME) during 2007-11. An extremely laborious and meticulous person she developed the Organic

Concept Paper for the organic conversion way back in 2003 while she was Deputy Director (Organic Farming) (2003-07). In 2004, she was handed over the additional responsibility of Agriculture Census. An individual with great deal of interest for minute details she has traversed across the state to comprehensively understand the problems of the farming community and believes in the earnestly addressing the issues. Person with strong academic background. she responsibly organized the Technical Sessions of the 2nd International Florishow held at Saramsa gardens, East Sikkim in February 2013. She has research, extension and capacity building interest in natural resources management especially soil fertility and management, soil survey and mapping, agriculture census, crop production constraints and organic farming. To her credit, she streamlined the entire process of food grain area and production data documentation in Sikkim as In-charge of Agriculture Census and EARAS. She has facilitated the establishment of Static Soil Testing Laboratory in three districts and two Mobile Soil Testing vans to undertake large-scale soil fertility evaluation in 2011-12. She was instrumental in developing and implementing Joint Project on Geo-Referenced Soil Fertility Mapping of Sikkim in 2012-13 with National Bureau of Soil Survey and Land Use Planning (NBSS &LUP), ICAR. Besides, she is involved with the development of State Annual and Five-Year Plan for the Department of Agriculture since 2002. Has also developed, and successfully implemented various centrally sponsored schemes and programmes of the state government. In the initial phase of her career she was appointed as Research Associate in 1981 and was promoted after a long term to Senior Soil Chemist in 1998 and subsequently to Soil Scientist during 1999 to 2003. An individual with creditable academic record, she has more than 40 publications as research papers in peer reviewed national and international journals/Proceedings, books, reports, technical bulletins, manuals, book chapters *etc*. and has travelled to Thailand and China, the experience gained has benefited the farming community of Sikkim.

Khorlo Bhutia, SAS, is the Secretary, Department of Horticulture and Cash Crops Development Department and Executive Director, Sikkim Organic Mission, Government of Sikkim. He assumed the position of Secretary in 2014 and Executive Director in 2012. After obtaining his Masters' degree in Agricultural Extension from Anand Agricultural University, Anand, Gujarat he joined Department of Agriculture, Government of Sikkim. Prior to his present position he was promoted to Principal Director of the same Department in 2013. During 2010-12 he served as the Director (Agriculture) and before that between 2005-10 Sh. Bhutia was Additional Director, Department of Horticulture. A thorough field-oriented and practical administrator he has travelled every bit of rural hinterland of Sikkim as Joint Director (200-04) and Deputy Director (1993-2000) addressing the farming needs of the farming community of the State. He has specialized in natural resource management, soil and water management, watershed management, minor irrigation, protected cultivation of flowers and vegetables and was involved in large-scale adoption of protected cultivation in Sikkim. He successfully implemented and managed various centrally sponsored schemes and programmes of the state government benefiting the farmers. He evinces great interest in all the possibilities of projecting the interest of Sikkim as a regular and vocal participant in every national and regional meeting/conference ensuring that the concerns of Sikkim are addressed. The initial phase of his career began as Agriculture Information Officer in 1979-80 and Soil Conservation Officer and Assistant Soil Survey Officer 1980-93. An avid learner, he has travelled to Israel, Taiwan, China and Thailand and the experiences gained have helped him to assist the farmers to reap more benefits.

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Contents

Agriculture in Sikkim: Transition from Traditional to Organic Farming

Khorlo Bhutia, Yashoda Pradhan, R. K. Avasthe and Phetuk T. Bhutia

Introduction

Agriculture is the mainstay of majority rural populace of Sikkim. The economy of the state is linked with agriculture that serves as the source of livelihood and economic security of sizeable native population. The growth, however, has been restricted because of biotic and abiotic factors. It is estimated that over 80 per cent of the rural population depends on agriculture and allied sectors for economic, food, and nutritional security. The agricultural systems practiced in Sikkim are integrated in nature that have evolved through years of experimentation by the farmers and withstood the test of time. A marginal improvement in the lifestyle of the farmers has been witnessed with the adoption of modern technologies.

Sikkim, basically an agrarian economy has a total geographical area of 7096 sq km, out of which only 10.5 per cent is available for cultivation. The net cultivated area of Sikkim has remained around 75,000 ha (inclusive of large cardamom plantations) for the last decade or so while the net cropped area has decreased due to diversion to non-agricultural uses like development of essential infrastructure.

Major crops of the State are maize, rice, wheat, millet, buckwheat, pulses and oilseeds. This sector contributes around 40 per cent towards SGDP. The totally hilly state has the agro ecological regions from sub-tropical to alpine in upper reaches. Most of the agricultural land is located around upto 1800 m elevation; however, in few cases it extends even up to 3000 m amsl. No single crop or a variety of crop suits all the elevations. Even though agriculture is crucial to the economy of the state it is largely rainfed with traditional systems of cultivation with low level of external inputs. Although rainfall in the state is quite high, yet due to inadequate effort in harnessing the available resources the area under the irrigation is hardly about 11 per cent.

The agriculture scenario is dominated by soil acidity, excess moisture during monsoon period and moisture stress during post monsoon/winter, heavy weed infestation, low temperature stress during winter, hailstorms in pre-*Kharif* maize (March-April), and incessant rain from May to September that causes leaching of nutrients and pesticides applied to *Kharif* crops. The prevailing climate favours high incidence of diseases and insect pests that drastically reduce the crop yields.

Agriculture in the hills had always been a challenge in the world. The technology interventions added during the last five decades have changed the face of agriculture in many developed and developing countries tremendously but failed to change the scenario of the hills. The State was untouched by the development that was taking place in the other parts of the country and the use of synthetic chemicals was already minimal and much below the national average. Additionally, owing to difficult terrain and low cultivable land where agriculture was practiced on a sustainable level, going the organic way was seen as an opportunity that was lying untapped. While organic farming practices along the hilly states generally revolves around securing livelihood on their small rainfed farming, the approach of Sikkim Government seeks to transform every inch of the soil into organically viable and sustainable land to promote Sikkim as brand entity of organic farming.

The factor productivity in Sikkim is lower than both the regional and national averages for all the major field crops. Increasing per unit productivity will be the key to bridging this gap which can be achieved with area expansion under high yielding varieties along with proper package of practices that will exploit the inherent production potential of varieties designed for organic farming from the local gene pool; soil-test values based nutrient management and appropriate plant protection measures. The per capita land holding has also seen a continuous fall since the 1970s owing to various reasons. The smaller the land holding size higher is the vulnerability for loss of various natural resources, particularly the soil. Besides, emphasizing on the conservation of natural resources it is very important to protect the fragile ecology, and in addition increase the productivity of different crops for attaining self-sufficiency in cereals, pulses and oilseed production and this is possible only with the concerted efforts on the part of all the stakeholders.

Most of the cultivable lands are terraced and farmers have settled on these holdings with established regular cropping

systems. Marginal holdings and small holdings clubbed together comprise about 50 per cent of all operational holdings and occupy 41 per cent of the total area. Inspite of limited cultivated land in Sikkim, agricultural development could make considerable progress in the last three decades.

Historical perspective

The Sikkim *Lepcha(s)* lived in harmony with natural resources, and their food habit was great variety of forest produce, chiefly tubers of different wild yams, and various leaves which were used as seasoning, both meat and vegetables were supplementary dishes to relish the cultivated cereals (Gorer, 1938). They were practicing slash and burn cultivation (*Zomal*), which consisted of clearing of forest in early spring (March) and all the debris set afire, after burning, the crops were sown in holes in soil made by pointed stick. The principal crops were dry rice and millets. After the harvest of rice or millets, field was sown with buckwheat, thereafter, land remained fallow for several years. It was the only possible way for maintaining soil fertility with least population pressure to prevent soil erosion and soil exhaustion.

The *Bhutia* tribe of Tibet as herdsmen came into Sikkim during the 16th Century in search of new pastures and trade markets. Their food habits were almost similar to those of the *Lepchas* and acquired the best land and cool hills. They also started slash and burn agriculture on good soil of hill slopes to satisfy their immediate need without disturbing the hill ecosystems. The *Nepalese* started to settle in large numbers in Sikkim in the beginning of 1800 CE and made the significant contribution for agriculture based on land utility. By the end of 1900 CE, almost every suitable part of land below 1800 m was cleared for agriculture (Risley, 1894). *Nepalese* settlers constructed the bench terraces to cultivate irrigated rice at the will of *Bhutia* landlords (*Kazis*). Initially, *Lepchas* were not interested in terraced cultivation. The British Government, after 1874-75 forced them to construct terraces and banned the destruction of reserve forestland. Thereafter, in almost one century, *Lepchas* themselves shifted from *Zomal* to terraced agriculture on slopy hills and former is non-existent at present. Forest, grasslands and agricultural land constitute the main ecosystems of the Sikkim Himalaya. The existing traditional agriculture systems of Sikkim hills are classified into *Dhankheti*, *Sukhakheti*, *Elaichibari*, *Kotheybari*, *Khasmal* and *Gorucharan*. Most of the present agricultural crops are cultivated as unaltered traditional systems developed through generations practicing recycling of nutrients from organic manure, crop residues, forest litter and local grasses/weeds. Diversion of the agricultural land to non-agricultural uses, population increase and family fragmentation has decreased the per capita land holdings of the net cultivated area.

Soils of Sikkim

On the basis of physiography, the whole state can be divided into 6 physiographic zones; summits and ridges; side slope of hills, narrow valley, cliff and precipitous slope, zone of glacial drift and perpetual snow cover (Anonymous, 1992). The entire state is a young mountain system with highly folded and faulted rock strata at many places. The Daling group of rock is found in the central part of Sikkim and composed of phyllites, schists, slates and quartzites. The northern central part of West Sikkim chiefly made up of Darjeeling gneiss. The gneiss of South Sikkim is highly micaceous and frequently passes into mica schists. The younger Gondwana contains sandstone, shale, and carbonaceous shale with occasional thin coal bands.

Soils of Sikkim have been classified (Das *et al.*, 1996) in to Inceptisol (42.84 per cent), Entisol (42.52 per cent) and Mollisol (14.64 per cent). Proximity to the Bay of Bengal and direct exposure to the south-west monsoon makes this region the most humid in the entire Himalayas. An amalgamation of conditions under the influence of heavy rains has generated sandy soils that are moderately to strongly acid in reaction, low exchangeable bases and rich in organic matter (Avasthe and Avasthe, 1996), high in available zinc, copper, iron and manganese contents and deficient in available boron and molybdenum (Avasthe and Avasthe, 1995). Soils also reveal considerable fixation of applied phosphorus. Of the four Districts of Sikkim, the frequency of soil having pH less than 5 are 50 per cent in North Sikkim while in the others it is about 12 per cent (Bhutia *et al.*, 1985). Soil degradation status showed that out of 7,09,600 ha total geographic area about 2,34,401 ha (33.03 per cent) was affected by water erosion causing low, medium, high and very high severity class of degradation. Soils affected by water erosion causing loss of top soils occupy an area of 2,28,331 ha (32.18 per cent). Water erosion also resulted in terrain deformation of 6,070 ha (0.85 per cent) (Das *et al.*, 1996).

Farming systems

The main ecosystems of Sikkim can be classified as forests, grasslands and croplands or agricultural lands. The agricultural lands can be placed in to *dhankheti*, *sukhakheti*, *elaichibari*, *kotheybari*, *khasmal* and *gorucharan* categories. Predominantly there are three agricultural seasons *viz.*, i) pre-*Kharif* or *sukhakheti* when maize is sown from mid-February to mid-March and sowing of ginger both as sole and intercrop along with maize; ii) *Kharif* season or *dhankheti* witnesses rice cultivation and iii) *Rabi*, during which oilseeds, wheat and vegetables predominate.

Livestock are a strong and integral component of rural Sikkim. They rear different species of animals for draught, milk, and meat purposes and they also supplement manure to meet the nutrient requirement of crops. The crop diversity decreases whereas the livestock varied with increase in altitude (Table 1). It was found that the prepared compost contained 1.1, 0.9 and 0.65 per cent N, P and K on dry weight basis, respectively.

1. Irrigated wetlands (*Dhankheti*): Rice is cultivated on terraces in nearly 12000 ha with 1757 kg/ha productivity during 2012-13 (Anonymous, 2013). Traditional cultivars still dominate the rice-growing scenario of Sikkim. Traditional cultivars like Attey, Kanchi Attey, Chirakey, Krishna Bhog, Dut Kati, Mansure, Phudungey, Kalo Nunia and many others occupy > 50 per cent area. They are adaptable but low yielders, susceptible to lodging and late maturing. Despite 'On-Farm' demonstrations conducted by the Department of Agriculture, Government of Sikkim using high yielding varieties the adoption levels reached 43 per cent with HYVs like HPR-1028, PD-10, KRH-2, KRH-4, Pusa Sugandh-2, *etc*. This is because of the 'palatability preference' for the traditional cultivars and their low harvest index whereby considerable straw produced is used as livestock dry fodder and cowshed bedding material, rendering the situation favourable for conversion to organic. Rice is followed by wheat, barley, potato, buckwheat, mustard, vegetables and fallow.

Table 1. Agro-ecosystems and crop components of Sikkim

Altitude range	Sub-agro ecosystems	Ecological adaptation	Crops
Lower hills (300-900 m)	Tropical	Wet and dry agriculture, sedentary farming, horticulture, livestock-goats, pigs, poultry, ducks, cattle and sheep	Agriculture and horticulture
Mid hills (900-1800 m)	Sub-tropical	Wet and dry agriculture, livestock, horticulture and minor forest produce, livestock-goats, pigs, poultry, ducks, cattle and sheep	Rice, maize millet, wheat, pulses, oilseeds, vegetables, potato, guava, lime, lemon, mango, ginger, mandarin
High hills (1800-2700 m)	Temperate	Dry agriculture, Bhutia transhumance, livestock-cattle, yaks, sheep, horses, mules	Rice, maize, millet, wheat, pulses, oilseeds, vegetables, potato, mandarin, plum, peach, pear, large cardamom
High hills (2700-4000 m)	Sub-alpine and Alpine	Yak herding, horticulture, pastoral economy (wool, cheese, butter, hides, and potato are commercial commodities), livestock-yaks, sheep, horses, mules	Maize, barley, vegetables, potato, apple, plum, peach, peas
Very high hills (4000-5000 m)	Alpine	Lachenpas and Lachungpas trans-humance, Lachenpas grow potato and vegetables, livestock-yaks, sheep, horses, mules	Mainly used for pasturage, seed potato and vegetables

Rice cultivation on terraces

2. Dryland (*Sukhakheti*): Maize occupies the majority of the cultivated area in entire Sikkim in more than 40,000 ha with a productivity of 1700 kg/ha during 2012-13 (Anonymous, 2013). Majority farmers still persist with the practice of growing maize by broadcasting the seeds, mostly due to shortage of farm labour. This often results in below optimum plant population, low use of fertilizers and heavy dependence on FYM were also resulting in low yields. The traditional varieties still dominate the scene of maize cultivation in Sikkim. These traditional varieties have over a period of time lost the crop vigour owing the open-pollinated nature of the crop. Hence, the crop yields are low in the range of 1.2 to 1.4 t/ha. A large number of crops are seen to be growing along with the maize crop as the intercrops. Maize in mandarin interspaces is also common.

3. Seed potato-based cropping system: Potato is grown in an area of 5148 ha with 4479 kg/ha productivity during 2011-12 (Anonymous, 2012). Sikkim produces seed potato that is harvested in August-September to reach the plains by November. Seed potato growing and marketing is a sort of monopoly of the Hilley area. Seed potato is followed by maize, peas, finger millet, soybean and fallow.

4. Ginger-based cropping system: Ginger, an important cash crop of the State is cultivated in 8900 ha with 5561 kg/ha productivity during 2011-12 (Anonymous, 2012). The cultivation practices in Sikkim are different and distinctive as compared to other parts of the country as it is grown on raised beds. Farmers reportedly apply very high quantities of FYM that could be up to 200 t/ha but commonly it is 40 to 60 t/ha. The planting material is all local and yields to the tune of 15 to 25 t/ha were recorded (Patiram *et al.*, 2001).

5. Fruit trees-based cropping system: Sikkim is known for its quality mandarin which is cultivated in an area of 8600 ha with a productivity of 3200 kg/ha while other fruits cover an area of 4795 ha and recorded productivity of 1353 kg/ha during 2011-12 (Anonymous, 2013). Mandarin, guava, papaya, peach, plum, and pear are the main fruit trees grown from tropical to temperate agro-ecoregions in the state from 300 to 1500 m on terraces with varying interspaces while apple is confined to Lachung valley 3000 m amsl. Given the small per capita land holdings the farmers exploit the interspaces to grow various crops. This practice is commonplace. Ginger, maize, turmeric, leguminous and non-leguminous vegetables, pulses are grown as intercrops. The cultivation of ginger and /or maize crops as intercrops generates negative impact on the health of the mandarin. The mandarin orchards are generally poorly managed without necessary sanitary and phyto-sanitary measures.

6. Homesteads (*Kotheybari*): In Sikkim, it is a widespread practice that the surroundings of rural dwellings are intensively utilized for cultivation of different tree species and rearing animals utilizing the domestic and farm wastes. The dwellings of the farming community of Sikkim are either on own land holding or on the fringes where vegetables,

fruits, flowers, traditional medicinal plants, fodder requirements are grown in the surroundings. Recent introductions are cymbidiums, gerbera, rose, carnation, gladioli, tuberose in floriculture, mushroom production (apart from collection of wild species), apiary, and fishery in small tanks (grass carp and magur). Bamboo is an invaluable plantation that plays an essential role in everyday life.

7. Vegetables-based cropping system: In harmony with the undulating topography, vegetable cultivation extends from foothills to elevations up to 2000 m amsl. Seasonal vegetables are cultivated on nearly 4081 ha with productivity of 5266 kg/ha during 2011-12 (Anonymous, 2012). The important vegetables of the state are:

i. *Kharif* vegetables: Brinjal, chillies, capsicum, French beans, cowpea, okra, cucumber, pumpkin, bottle gourd, sponge gourd, ridge gourd, snake gourd, bitter gourd, sweet gourd, balsum apple, chayote, *etc.*

ii. *Rabi* vegetables: Cabbage, cauliflower, broccoli, garden pea, French beans, radish, carrot, turnip, spinach, amaranths, fenugreek, leafy mustard, lettuce, celery, coriander, leafy onion, garlic, leek, potato, colocasia, elephant yam, *etc.*

iii. Off season vegetables: Cabbage, cauliflower, broccoli, Brussels' sprouts, radish, carrot, tomato, green pea, French beans, spinach, leafy mustard, chayote, cucumber, amaranths, leafy onion, summer potato, capsicum, asparagus, bamboo shoots, fern shoots, stinging nettles, mushroom, *etc.*

iv. Off season vegetables cultivation: Many off-season vegetables are cultivated on more than 5540 ha with 5531 kg/ha productivity during 2011-12 (Anonymous, 2012). The agro-climatic conditions of Sikkim are congenial for local and exotic vegetable cultivation throughout the year. The common and commercial off-season vegetables are summer potato, summer tomato, capsicum, chillies, tree tomato, cabbage, cauliflower, broccoli, Brussels' sprouts, radish, carrot, turnip, beet root, garden pea, French beans, chayote, cucumber, green pumpkin, amaranths, spinach, leafy mustard, leafy onion, leek, mushrooms, buckwheat leaves, *etc.*

8. Flower-based cropping systems: Sikkim, land of orchids with more than 450 species possesses fascinating floral diversity; approximately 4500 species of flowering plants are reported to occur in this region. Interestingly, Sikkim, which is a meagre 0.2 per cent of the geographical area of the country is bestowed with more than 26 per cent of the flowering plants of India. Orchidaceae, Cyperaceae, Juncaceae, Ericaceae, Rosaceae, Saxifragaceae were well represented in the state of Sikkim. These apart, species belonging to Leguminosae, Scrophulariaceae, Primulaceae, Rosaceae, Zingiberaceae displayed considerable presence (Singh and Chauhan, 1997). Flowers gained importance as commercial crops during the last decade. Orchids, gladioli, gerbera, anthurims, liliums, rose, asters, marigold and carnation are grown as mono-crops. Gladioli are grown as intercrop with maize also. Flowers both cut/pot flowers and plants/bulbs together are grown on nearly 210 ha with more than 23 lakhs numbers of flower production during 2011-12 (Anonymous, 2012).

9. Spices-based cropping system: Major spices of Sikkim include large cardamom, ginger, turmeric, Red cherry pepper (*Capsicum annuum* var. *cerasiforme*) and Bay leaf (collected from the forests, *Cinnamomum impressinervium*). Turmeric is also grown both as sole and intercrop (with maize) like ginger as stated earlier during pre-Kharif season. Red cherry pepper a prized spice is cultivated during *Kharif* and sold at premium prices from Rs. 80 to 200/- per kg. Large cardamom occupies the largest cultivated area and revealed typical growth requirements that necessitated special mention amongst the spices of the state.

10. Large cardamom agroforestry: Very large forested areas exist in Sikkim with rural populace participation in joint forestry management being the states' priority. The largest agroforestry system is large cardamom (*Amomum subulatum* Roxb.)-based that supports as many as 23 tree species. India is the major producer of large cardamom, however, the plantations are limited only to the sub-Himalayan Sikkim, Darjeeling district of West Bengal and some NE states. Normally large cardamom has been observed to thrive well in association with the Himalayan Alder (*Alnus nepalensis* D. Don) and hence, this alliance is also called as the large cardamom-Alnus agro-forestry system.

Mainly five popular cultivars *viz.*, Ramsey, Golsey, Seremna, Varlangey and Sawney were common in Sikkim. Several others include Ramla, Chivey, Ramsey, Ramnag, Madhusay, Seto Golsey, Slant Golsey, Red Sawney, Green Sawney and Mingney, and Varlangey Golsey. Generally, August-September for low and mid altitudes and November-

December for high altitude are the periods of harvesting. The average yields range from 100 to 400 kg/ha of dry large cardamom (Pradhan and Avasthe, 2005). India is today the largest producer of large cardamom in the world with 54 per cent share, followed by Nepal (33 per cent), and Bhutan (13 per cent). Its fruit (capsule) is used as spice/condiment and out of 4000 metric tonnes of annual output of large cardamom in the country, >50 per cent comes from Sikkim as the state's major income earner.

Traditional agro forestry systems in Sikkim

A. Sub-tropical and mid hill temperate zone

The study revealed that nine major agroforestry systems were in practice in the sub-tropical and midhill temperate zones. These two zones did not reveal key differences in the crop or animal component while tree component differed nearing elevation of 1800 m. The systems were agri-horticultural, agri-horti-pastoral, agri-silvi-pastoral, horti-silviculture, agri-horti-silvi-pastoral, livestock-based mixed farming, sericulture-based farming, bamboo-based farming, homesteads and tea plantation.

***Agri-horticultural system*:** Cultivation of sole maize, as an intercrop with ginger, turmeric, buckwheat, beans, pulse-type beans, tapioca and Sikkim mandarin-ginger/turmeric system is most widespread in this system. In fact, maize occupies the highest acreage of 40,000 ha in the state. Local cultivars dominated the scenario of the various crops cultivated along with Sikkim mandarin and avocado. Sikkim mandarin + maize + ginger/turmeric intercropping witnesses very heavy application of organic sources that ranges from 40 to 100 t/ha. Prominent ginger cultivars are Bhaise and Gorubathane. Various kinds of vegetables are also cultivated mostly for self-consumption. Cultivation of flowers such as cymbidium orchids, gladioli, carnation, gerbera, rose, lilies, tuberose and marigold is also gaining momentum.

***Agri-horti-pastoral system*:** In this system intercropping of cereal, oilseeds, pulses, beans, millets, and spices like ginger and turmeric are cultivated in the interspaces of Sikkim mandarin, avocado, guava and lemon trees. Broom grass is used as a vegetative barrier for soil conservation and performed the role of winter fodder for the cattle, pigs and goats. Collection of ferns, nettles, and other wild edibles is also common practice.

***Agri-silvi-pastoral system*:** Crops such as maize, wheat, pulses, buckwheat, oilseeds, beans and Finger millet are grown in association with trees that are used a fuel wood or crude timber and winter fodder.

***Horti-silviculture system*:** This is perhaps the best kind of synergism recorded where large cardamom *(Amomum subulatum Roxb.)* thrives extremely well under the shade of more than 10 species of tree species. It performs the best under the shade of alder (*Alnus nepalensis*).

***Agri-horti-silvipastoral system*:** In this system maize, tapioca, ginger, beans, pulses, oilseeds and other crops are grown in association with tree species that fulfil the fruit, fuel wood and fodder requirement. Small holdings of large cardamom are also recorded in this system.

***Livestock-based mixed farming*:** Animal rearing is common to perhaps all the systems irrespective of land holding size. Even landless residents maintain various animals. This placed tremendous pressure on the natural resources. The annual consumption of green fodder and fuel wood ranges from 300-400 tonnes and 70-80 tonnes, respectively, in the subtropical zone, where agriculture is more intense than the higher agro-ecological regions. Green fodder fed to the animals comprises foliage of various shrubs and tree species. Most of the animals are traditional, low yielding breeds.

***Sericulture-based farming*:** Silkworms are reared on the foliage of mulberry (*Morus laevigata*) and *Terminalia* spp. In the interspaces available crops such as pulses, oilseeds, oats, millets and broom grass are cultivated.

***Bamboo-based farming*:** The general observation regarding poor rate of survival of vegetation under the shade of bamboo is an issue of larger discussion. Nevertheless, ginger, turmeric, large cardamom and rice bean grow well up to a distance of 11 to 15 m from the bamboo rows. 10 genera and 24 species of bamboo are reported from this small state.

The tender shoots of *Chimonobambusa hookeriana* (Munro) Nakai, *Dendrocalamus hamiltonii* Nees & Arn. ex Munro., *Drepanostachyum intermedium* (Munro) Keng f, *Himalayacalamus falconeri* (Hook. f. ex. Munro) and *Phyllostachys bambusoides* Sieb. & Zucc. are consumed in different ways often considered a culinary delicacy (Singh, P. 2000. BSHC, Gangtok. *Pers. Commun.*).

Homesteads: The dwellings of the farming community of Sikkim are either on own land holding or on the fringes where vegetables, fruits, flowers, traditional medicinal plants, fodder requirements are grown in the surroundings. Different kinds of animals are also maintained. Gerbera, carnation, cymbidium, alstroemerias, gladioli, tuberose, rose, lilies in floriculture, mushroom production (apart from collection of wild species), apiary, and fishery in small tanks (grass carp and magur) are commonly reared.

Tea plantation: The State Government maintains one tea (*Camellia sinensis*) plantation of >500 ha in the altitude range 1550 to 1800 m amsl. Wild cherry (*Prunus cerasoides*) is planted on the boundaries and as avenue trees. The organic tea produced here is highly rated at the Kolkata tea auctions.

B. Temperate zone

Only three agroforestry systems are observed in the temperate zone *viz.*, agri-horticultural, horti-silvi-pastoral and livestock-based mixed farming. The human population density is lower than the earlier two altitude zones. Adaptability of crops to the climate decreases at the higher altitudes and that reduces the farmers' options in the subalpine zone.

Agri-horticultural system: Here the tree components are just two, namely, Sikkim mandarin and apple. Apple is now becoming rare. Buckwheat, maize, barley and some vegetables are cultivated to utilize the interspace. Rice is grown up to an altitude of 1800 m amsl. Seed and table potato and maize are preferred.

Horti-silvi-pastoral: Maize, millets, and vegetables like potato (seed and table), cole crops, peas, beans, radish and leafy mustard {*Brassica juncea* var. *rugosa* (*Raya sāg*)} are grown along with Sikkim mandarin (up to 2000 m) and apple. Large cardamom grows well as an under growth of various tree species up to an altitude of 2000 m amsl.

Livestock-based mixed farming system: Animals are an integral component of all the agroforestry systems. At the high altitudes maintenance of sheep and nomadic herds of *dzo's* (semi-domesticated, cross-bred offspring of yak reared for milk and a range of by-products) is recorded. Grazing pressure increases at the higher altitudes as most of the fodder needs are collected from the wild despite a blanket ban by the State Government.

C. Subalpine zone

At the higher altitudes the climate reduces the agroforestry systems to one in each zone. Horti-pastoral-transhumance and livestock-based mixed farming (beyond timberline)-transhumance are recorded in the subalpine and alpine zones, respectively. The local community comprising mostly of the *Bhutias* migrate to the higher altitudes from April to November every year and barely a few stay back. The semi-domesticated *dzo* herds graze at the higher altitudes and the survivors of the harsh winters of the higher and trans-Himalayas are re-gathered by the owners the next summer. The extremities of the climate reduce the options to animal-based ones, one in each zone.

Horti-pastoral-transhumance: Vegetables perform very well though the alternatives are few. Potato (seed and table), cole crops, peas, beans, radish and leafy mustard {*Brassica juncea* var. *rugosa* (*Raya sāg*)} produce yields comparable with any other place. Maize could grow well up to 2000 m amsl. Yaks, mules maintained for transportation and animals like sheep and *dzo's* are all nomadic grazers.

D. Alpine zone

Livestock-based mixed farming trans-humance: The system here is fully animal based with the economy largely driven by the yak both as a source of livelihood and mode of transport for humans and materials. The human population is small that indulged in the production of small quantities of potato, leafy mustard {*Brassica juncea* var.

rugosa (*Raya sāg*), and radish and also cabbage and peas up to 4200 m elevation. The timberline is recorded at 4200 m amsl. The vegetation is mostly herbaceous with woody species of *Rhododendron lepidotum*, *R. setosum*, *R. anthopogon*, *Juniperus prostrata*, *J. recruva*, *Betula utilis* and stumps of *Tsuga* sp. up to 4200 m. Grazing herds of sheep and dzo's are maintained for meat, milk and other by-products. The pressure on natural resources and animal mortality rate is very high (Avasthe, 1996).

Nutrient management in traditional agriculture

The farmers of Sikkim make conscious efforts to retain high levels of organic matter in their field through continued use of organic manure as compared to other parts of the country to replenish the nutrient losses through crop removal and erosion. The use of chemical fertilizers in 1999-2000 was 7 kg N, 4.5 kg P and, 1.0 kg K per ha, respectively in the state (Pradhan, Y. 2001. *Unpublished Pers. Communication*), which was far below the national average. Most of the fertilizer was used in maize and potato only. Livestock forms an integral part of village life of Sikkim. They rear different species of animals for draught, milk, and meat purposes and these animals also provide manure to meet the nutrient requirement of crops. In the mixed farming systems, nutrient balance depends mainly on the number of animals, their housing, feeding and cultural practices. However, balance was also affected by storage and distribution methods, which should be arranged to minimize losses and the danger of pollution. It is found that the prepared compost contains 1, 0.4 and 1 per cent N, P and K on dry weight basis, respectively. The available compost in Sikkim can supply 1354, 541 and 1354 tonnes N, P and K annually to supplement the nutrient requirement of crops. This amounted almost to 22, 9, and 22 kg NPK per ha net cultivated area, which is very high availability. However, the use is not similar in all the crops grown, the common pattern of use of compost is given below.

Ginger	50 per cent
Vegetable	15 per cent
Others	35 per cent

The use patterns and systems of organic manure based specific farming systems are briefed below.

Ginger + maize on raised beds

It is the old but reformed system of production, which almost did not use any form of chemical fertilizer or other chemicals and totally depended on organic sources for production. It is a cash crop and cultivated on more than 5000 ha area. Cultivation is done on raised beds. Maize seeds are sown either around the periphery of beds or in the space made between two beds and whole beds are covered with leaves and twigs of various forest trees, weeds, grasses available around the field, animal bedding and surplus rich straw as a mulch amounting 5-20 t/ha on dry basis. In the opinion of farmers, ferns, *Chromoleana odoratum*, and animal bedding are best mulch for higher productivity of ginger and *Cylindrica imperata* (*Seeru*) and leaves of *Schima wallichii* (*Chilaune*) are of inferior quality.

The raised beds method of ginger cultivation is sustainable because of recycling of nutrients through organic manure. Even farmers get more yield of inter-crop maize compared to sole crop as a result of heavy quantity of manure application to ginger main crop. Maize also provides shade during the early period of ginger growth and after harvesting open space favours the development of bolder rhizomes. The mulch keeps the soil shaded and warm, prevents weed infestation, minimizes soil erosion and protects the young plants from heavy rain. After decomposition, manure and mulch not only meets the needs of growing plants, but also enrich the soil nutrient status (Patiram *et al.*, 1995). The organic manure and mulch loosen the soil for the proper development of rhizomes, so farmers prefer organic manuring for ginger cultivation.

Potato cultivation

Sikkim potato is famous for seed, which is harvested in August-September and reaches the plains for seed by November. Seed potato growing and marketing is a monopoly of the Hilley seed potato belt. In this belt farmers prepare the compost by using collected forest litter and animal bedding along with animal excreta in pits. In the month of December and January, after the ploughing of field, all the residue of crops and weeds are collected in heaps and covered with soil. The heaps are burned and residue left after burning spread over the field. 15 days before sowing of seed potato (January to March), the un-decomposed portion of the prepared composed is separated and good quality of manure is heaped near the field. The enriched compost is applied in furrows at the time of potato seed sowing. Pea is inter-cropped giving space for 4-5 furrows of potato between each row to avoid the shading effect. In Lachen and

Lachung valleys of North Sikkim, farmers burn the residues openly entirely on the field and then mixed in the soil by ploughing. The method of sowing is almost same.

Zero-tillage cultivation of cabbage in Lachung

During April and May, growers cut the grasses, weeds and stubble with sickles on slopy lands and after drying, burn the same on entire field. Before the planting of cabbage seedlings, farmers practice shallow digging of field without any input. Growers used to apply top-dressing of urea after 30 and 60 days of transplanting of cabbage seedlings because of market facility provided by the state government.

Vegetable cultivation

All the other vegetables (beans, cabbage, cauliflower, pea, radish *etc.*) are based on organic manuring cultivation. Organic manure is almost fully applied in furrows to get maximum output with least losses by erosion.

Relay cropping of Rice bean, French bean, pea and soybean with maize

Rice bean is grown as relay crop with maize only at higher altitudes whereas soybean is commonly cultivated everywhere. Pea and French bean are inter-cropped in small area near the house. Both crops are inter-cropped in May-June in the standing maize field during the time of inter-culture. After the maturity of maize plants, cobs are harvested leaving the stalks in the field for the support of inter-cropped Rice bean, French bean, and pea, however, only half stalk is left in case of soybean.

Legumes in rotation

Rice bean and urd bean are cultivated in rotation after the harvest of maize everywhere in the mid and low hills of Sikkim. Rice bean is a non-determinative type of legume, which enriches the soil by adding large amount of foliage and fixed N as compared to other legumes.

Homesteads (*Kotheybari*)

In Sikkim, it is a common feature especially with *Lepcha*(*s*) and *Bhutia* tribes, house is a field fenced in with bamboo, fruit and other trees. The complex mixture of trees and annual crops (food and vegetables) allows the continuous use of land around the house throughout the year. This garden is only the portion of land which receives animal manure; it is beside the house, under which domestic animals shelter at night; dung is collected there for compost preparation and residue is continuously thrown over the fence. At the bottom of nearly every garden is a plantation of bamboo, cultivated so as to have an easily available supply of this invaluable material.

Relevance of the technology adopted by the farmers

Most of the cultivated land of Sikkim is terraced /semi-terraced and farmers are settled in their holdings in most of the area. As stated earlier, the inhabitants of this mountain state had realized the importance of slash and burn agriculture to replenish the loss of soil fertility with abundant availability of land and least population pressure. With the passage of time, they started settled cultivation on the basis of their traditional wisdom to transform agriculture based on organic manure and inclusion of legumes in cropping systems to maintain the sustainability of land. It is practical because of the availability of organic manure and other resources to the farmers. The soils of the entire north-eastern hill states are highly deficient in phosphorus (Prasad *et al.*, 1981), whereas 2/3rd soils of Sikkim are medium to high in availability (Bhutia *et al.*, 1986), as a result of recycling of nutrients through organic manuring. There is considerable evidence that organic matter reduces the soluble and exchangeable aluminum by forming Al-organo complexes in soil (Hoyt and Turner, 1975; Ahmad and Tan, 1986). The field study conducted on acid-Al toxic soil of Sikkim revealed that the benefit of fertilizer could be increased by the continuous application of FYM to each crops without liming (Patiram, 1996).

Generally, it is observed that organic manure based farming systems increases the buildup of soil organic matter, which reduces the erosion, runoff and transport of organic and inorganic matter to streams and rivers, besides, improving the physical, chemical and biological properties of soils from fertility point of view. In addition to highest

degree of yield stability, organic manure can also reduce the pest and disease incidence by increasing species diversity, promote fungi population to control nematodes, absorb and inactivate pesticides and provide food for marginal pests to decrease their severity (Edwards, 1990). The burning of crop residues and weeds (shrubs and herbs) for the cultivation of potato and cabbage temporarily raise the soil pH, increase the availability of nutrient and decrease the incidence of insect-pests and diseases (Nye and Green, 1960). The leguminous species in inter-crops and as sole crop contribute the fixation of N and organic matter is formed by the decay of leaves and rotting branches and roots, improve the soil productivity through nutrient recycling in the system.

Blending of indigenous technology with scientific techniques (pre-conversion)
The soils of Sikkim are acidic in reaction and susceptible to various kinds of degradation due to high rainfall and hill agriculture (Das *et al.* 1998). The consumption of chemical fertilizers up to 2002 was below 10 kg/ha and yield of most of the crops well below the national average production caused by the low level of the adoption of the package of practices and other biophysical constraints. Sustainable agriculture includes the ongoing production to maintain equilibrium with the changing demands of a growing population in view of the problems of removal and environmental degradation. Expensive chemical fertilizers made it necessary to maintain livestock to recycle nutrients and build up of organic matter in soils to get the continuous sustainable production.

Introduction of new crops including wheat, rajmash, rape and mustard; extension of more areas under high yielding and improved varieties of cereals; increased use of fertilizers and pesticides and expansion of area under double or multiple cropping were the landmarks in converting agriculture into a viable venture from mere subsistence farming. The availability of basic infrastructure aided in enhancing the production and productivity of crops in the State. In late eighties, the priority was on the development of horticulture and cash/commercial crops. These changes were significant indicators of the on-going process of agricultural transformation from cereal-dominated subsistence agriculture to high value, cash crop dominated commercial horticulture.

Crop production situation analysis

Pre-organic conventional period

The traditional cultivars still dominated the cereal cultivation scenario despite the efforts of the Department of Agriculture, Government of Sikkim. The local and composite varieties popular earlier have slowly but surely been replaced with hybrids/HYVs. Yet, the production and productivity trends in Sikkim were much below the regional and national averages and far from inspiring. This could be ascribed to factors such as low use of fertilizers and timely non-availability of fertilizers and other inputs. The highest consumption level was in 2002-03 at 21.5 kg/ha was almost double of 12.3 kg/ha in 2000-01. The use of chemical fertilizers was 12 kg N, 8.5 kg P and, 1.0 kg K per ha, respectively in the state, which was far below the national average (Pradhan,Y. 2004. *Unpublished Pers. Communication*). Most of the fertilizer was used in maize and potato only.

The crop production scenario of Sikkim during 1998-99 to 2002-03 under conventional agriculture showed erratic pattern in total food grain production and productivity (Table 2). The area under food grain production showed a gradual decline from 78,070 ha in 1998-99 to 72,090 ha in 2002-03 whereas the oilseed producing remained relatively constant at less than 10,000 ha. This perhaps resulted from diversion of agricultural land to non-agricultural uses. Maize, rice, wheat, finger millet, barley and buckwheat were the main cereals. Acreage under maize, rice, wheat and finger millet decreased whereas the cropped area of barley increased marginally and that of buckwheat remained constant between 1998-99 and 2002-03. The production and productivity of maize was highest during 2000-01 whereas rice, wheat, finger millet, barley, buckwheat, and urd recorded peak performance during 1999-00. The total food grain production (1,03,210 MT) and productivity (1357 kg/ha) was highest during the year 2000-01. Rapeseed and mustard and soybean were the main oilseed crops that also recorded best performance during 1999-2000.

Table 2. Area (ha), production (`000 tonnes) and productivity (kg/ha) of field crops of Sikkim from 1998-99 to 2003-2004 under conventional agriculture

Crop	Particulars	1998-99	1999-00	2000-01	2001-02	2002-03
Cereals						
Maize	Area	39.38	39.39	39.90	40.11	36.70
	Production	50.80	52.83	59.61	57.01	53.72
	Productivity	1289.92	1341.21	1494.00	1421.00	1449.07
Rice	Area	15.87	15.91	15.22	14.90	14.79
	Production	21.96	23.44	21.36	21.37	21.22
	Productivity	1383.20	1473.47	1403.00	1434.00	1434.75
Wheat	Area	7.91	8.10	7.21	6.70	6.33
	Production	6.42	12.85	10.10	9.93	8.86
	Productivity	807.98	1586.39	1400.00	1482.00	1399.68
Finger millet	Area	5.00	4.99	4.56	4.93	4.34
	Production	4.71	4.71	4.23	4.46	3.74
	Productivity	942.62	944.93	928.00	905.00	861.75
Barley	Area	1.13	1.14	1.14	1.18	1.23
	Production	1.22	1.68	1.21	1.45	1.50
	Productivity	1076.99	1471.05	1061.00	1230.00	1219.51
Buckwheat	Area	2.00	2.05	1.99	2.01	2.00
	Production	1.55	1.59	1.53	1.45	1.54
	Productivity	758.77	775.66	769.00	723.00	770.00
Pulses						
Urd	Area	4.40	4.40	3.78	3.78	3.78
	Production	3.05	3.31	2.75	2.71	2.79
	Productivity	693.09	752.18	727.00	717.00	738.10
Other pulses	Area	2.30	2.31	2.25	2.86	2.90
	Production	2.55	2.64	2.442	3.21	3.47
	Productivity	1107.00	1141.34	1074.00	1121.00	1196.55
Total Food grain	Area	78.07	78.29	76.06	76.47	72.09
	Production	92.25	103.05	103.21	101.59	96.33
	Productivity	1181.63	1316.27	1357.00	1329.00	1336.25
Oilseeds						
Rapeseed and mustard	Area	5.68	5.76	5.76	5.80	5.88
	Production	2.41	4.16	3.94	4.04	3.95
	Productivity	424.74	723.02	684.00	697.00	671.77
Soybean	Area	4.02	4.15	4.15	4.15	3.88
	Production	2.75	3.41	3.41	3.31	3.14
	Productivity	682.98	820.92	822.00	799.00	809.28

Other oilseeds	Area	0.08	0.08	0.08	0.08	0.06
	Production	0.04	0.03	0.03	0.04	0.04
	Productivity	500.00	425.00	425.00	500.00	500.00
Total oilseeds	Area	9.78	9.99	9.99	9.99	9.80
	Production	5.20	7.60	7.38	7.39	7.13
	Productivity	531.70	760.76	7.39	740.00	727.55

Source: Pradhan and Avasthe (2005)

General agriculture policies

The State is entirely hilly with no plain land. The agro climatic condition ranges from sub-tropical type in the lower valley to alpine condition in the upper reaches. No single crop or the variety of crop suits all the elevations. Beginning 1975 the development in agriculture took a turn where the whole farming approach changed due to the influence of Green Revolution. Regional concept for the development in agriculture and horticulture was introduced in the various agro-climatic zones of the State. In order to undertake adaptive trials, seed production and for the development of package of practices for different crops suitable to the respective regions Government farms were established.

The uses of chemical fertilizers was popularized using the recommended dose of fertilizers after evaluating the fertility with the establishment of Soil Testing Laboratory. The use of chemical fertilizers, chemical pesticides, improved varieties and the increase in cropping intensity helped to increase the food grain production continuously. Almost all the agriculture inputs used were distributed free of cost in the form of demonstration and as mini-kits of new varieties in order to popularize the technology. However, in case of Centrally Sponsored Schemes the programmes were being implemented as per the guidelines.

After 1995 the area under different crops decreased due to diversification from traditional crops to low volume high value crops, however, the productivity kept on increasing due to integrated nutrient management practices in crop production.

The farming practices followed in the State were very unique owing to diverse circumstances. It was found that these practices, coupled with harsh conditions in the mountains could be leveraged to the advantage of the State to propagate Organic Agriculture. Some of these practices and hardships are as follows:

Hardships faced	Unique practices followed
1. Topography of Sikkim presents slopy lands with poor soil depth and fragile eco-system.	1. Most farmers still follow traditional farming practices.
2. Most vegetables, food grains and fodder are imported from the plains.	2. For farming to take place, presence of natural resources like forest, livestock *etc.* are a must. An 'integrated system' approach is carried out instead of focusing on any single factor.
3. Farming is practiced on terraced type fields where the soil is sandy to sandy loam. With the result, leaching losses are high.	3. Livestock is maintained for generation of FYM and milk is a by-product.
4. There are marginalized land holdings in the State. Conventional farming cannot take place effectively in small tracts of land.	4. Very negligible use of chemicals is being done by the farmers (about 10.26 kg/ha).
5. In the State, very fragile environment exists which needs to be looked after.	

It was found that the above aspects, coupled with the evils of green revolution automatically lent support to Organic Agriculture, which could transform these constraints to an opportunity.

Organic policy

When organic farming was in its nascent stage in India, leadership in the Sikkim not only propagated the importance of organic farming but also implemented it with full fervor. Farming system in Sikkim is traditionally organic. Before 1994-95, much effort was made towards popularizing chemical fertilizers and their application and farmers were advocated for use of fertilizers like urea, DAP and MOP for obtaining N:P:K, but due to topographical variation, rate of adoption, rural social fabrication, and complex set up of farming community, the use of chemical fertilizers was very low. The Table 3 depicts the consumption pattern and rate of decline of fertilizer consumption in the State.

Table 3. Per hectare consumption of fertilizer (N:P:K) of hill states in India (kg/ha)

States	1986-87	1990-91	1995-96	1996-97	1997-98
Arunachal Pradesh	0.08	1.79	1.6	2.2	2.2
Assam	4.59	10.18	9.7	14.6	21.9
Himachal Pradesh	26.56	35.49	30.6	35.5	36.5
Manipur	29.95	43.68	43.6	48.6	49.7
Meghalaya	16..49	12.32	11.8	14.4	15.0
Mizoram	0.08	11.19	6.9	3.4	10.2
Nagaland	0.23	5.30	2.4	3.9	4.8
Sikkim	**26.01**	**10.11**	**8.3**	**5.9**	**5.8**
Tripura	1.55	20.72	18.4	18.8	29.3

Source: Fertilizer Statistics. 1997-98, Fertiliser Association of India, New Delhi

This shows that the fertilizers consumption rate in the State was 26.01 kg/ha and was third highest among hill states in 1986-87, this figure decreased to 5.8 kg/ha in the year 1997-98.

Agriculture in Sikkim generally was practiced under low input situations with < 20 and < 1 kg/ha fertilizer and plant protection chemicals consumption, respectively in 2002-03 (Pradhan, Y. 2003. *Pers. Commun.*) Keeping these in mind, the Government of Sikkim made declaration of the policy to transform Sikkim into totally "Organic State" by passing a resolution in the Sikkim Legislative Assembly in 2003, with the intention of cultivating export-oriented organic crops. A policy for elimination of all forms of chemicals from agriculture scenario is being implemented to switch whole agriculture into organic employing options such as enriched rural compost, vermicompost, biofertilizers, green manures and organic amendments/fertilizers (dolomite, rock phosphates) and other similar sources of nutrition. Capacity building of the farmers on effective utilization of these options is part of the policy. Crops scenario was dominated by traditional cultivars grown from time immemorial in Sikkim that did not respond to fertilizer application and deserved replacement with high yielding varieties for various reasons. Many problems were associated with the continued use of traditional crop cultivars under low nutrition where farmyard manure was normally the major nutrient source. This often resulted in unhealthy plant growth, poor yields accompanied by loss of topsoil. Sub-optimal plant population of crops grown too was not uncommon in the farmers' fields. Various agencies of soil erosion were at work at all times and under poor vegetation cover their impact was considerable. The cultivation practices did not reveal major variations even where the high yielding varieties were introduced, however, there may have been exceptions. While loss in the natural resource base occurred through geological processes such as landslides and mass wasting under the influence of certain

factors, often the cause was anthropological.

The majority of the farming in Sikkim could be termed 'near organic' or 'organic by-default'. In view of the above this was a positive decision since the conversion period would be small (phasing out of chemical fertilizers *etc.*) with a rider of the inability of organic manures in exploiting the inherent yield potential of the recently introduced improved or high yielding varieties without the organic farming technology in place. The latter was the challenge as well as the future research thrust area since most of the agriculture systems were at the subsistence levels, multiple cropping would increase the cropping intensity and land use efficiency through alternate options such as improved varieties of crops and technologies, planting fruits, fast growing fodder, fuel and timber tree species. Crop productivity varied within the farms in the micro-watershed because of variations in inputs like labour, seeds and quantity and quality of manure. Basic research to evaluate the minimum requirements of different inputs was warranted. Management of on-farm production and use of organic compost was required to receive immediate attention.

With the State Government decision of converting the agrarian practice of the State fully organic based, few landmark promotional activities had been done by the Department:

- A concept paper on going toward Organic Farming was prepared with road map in the year 2004.
- The chemical fertilizer consumption was reduced every year by tapering-off of subsidy by 10 per cent on fertilizers. The subsidy is nil from the year 2007-08.
- The Department made lot of efforts to supplement the nutrient requirements of the crop plants by organic sources only by adopting various technologies of recycling the farm wastes like rural composting, vermicomposting, EM composting, biodynamics, *etc.* and making the State chemical-free.
- Eight units of Vermiculture Hatcheries had been established in five Government Farms and three KVKs of the State from the year 2006-09.
- Biofertilizer production unit had been established in the state.
- In organic farming, importance is being laid on the improvement of soil health. Collection of soil for testing is mandatory in order to evaluate the fertility status and the physical properties of soils under organic farming. The State has four static Soil Testing Laboratory one in each district and two Mobile Soil Testing Vans.
- Integrated pest management is being encouraged for plant protection. Bio-control agents are being purchased by the Government for disease and pest control. However, plant protection is the challenge in organic farming. It is always prevention is better than cure in this system of farming.
- Towards capacity building the Government is training all the farmers to make appropriate changes in the package of practices and adoption of better technologies. The Government is training officers and field functionaries within the State as well as outside the State. The Extension Officers are being sent to visit various places where the organic farming is in advanced stages.
- After the establishment of the infrastructure in post-harvest technology, Seed Processing Centre at Mazitar and Jorethang, efforts are also being made by the Department to produce seeds of desired varieties locally to meet the domestic requirement instead of depending on the outside sources.
- Vermicompost unit having capacity of 50 MT have been established in two Government farms.
- State Organic Mission (SOM) was launched in the year 2010 on the occasion of 15th August for strengthening organic process in a holistic manner in the State. On the occasion of Independence Day, 15th August 2010, the Hon'ble Chief Minister of Sikkim made an appeal to Citizens declaring Statewide SOM.

Launching of Sikkim Organic Mission by Hon'ble Chief Minister on 15th Aug.2010

Objectives

i. To reshape and revamp the Department strategy and implementation of programme/schemes giving a shape of an organic module.

ii. Sensitization of rural mass and work force through capacity building programmes.

iii. Predetermined size of area of 50,000 hectares of land to be brought under ICS and organic certification between the years 2010 to 2015.

iv. Operationaliztion of livelihood schools, where each school has enrolled 80 trainees for each trimester (3 month of training programme) to come out as service provider for ICS.

- A target has been set up to bring 50,000 hectare land for organic certification in phase-wise manner *i.e.*, between the year 2010 to 2013, 18,000 hectare of land to be brought under Internal Control System (ICS) and organic certification, and between 2011 to 2014 another 18,000 hectares under ICS and organic certification and 2012 to 2015, another 14,000 hectares of land under ICS and organic certification in farmers' field making Sikkim a totally organic state by 2015.

Organic conversion period

Sikkim was declared 'organic' in 2003 strengthening the environmental protection efforts of the state taking advantage of the low fertilizer use. Perhaps the government also intended to improve the economy of the farmers by marketing the organic products at a premium.

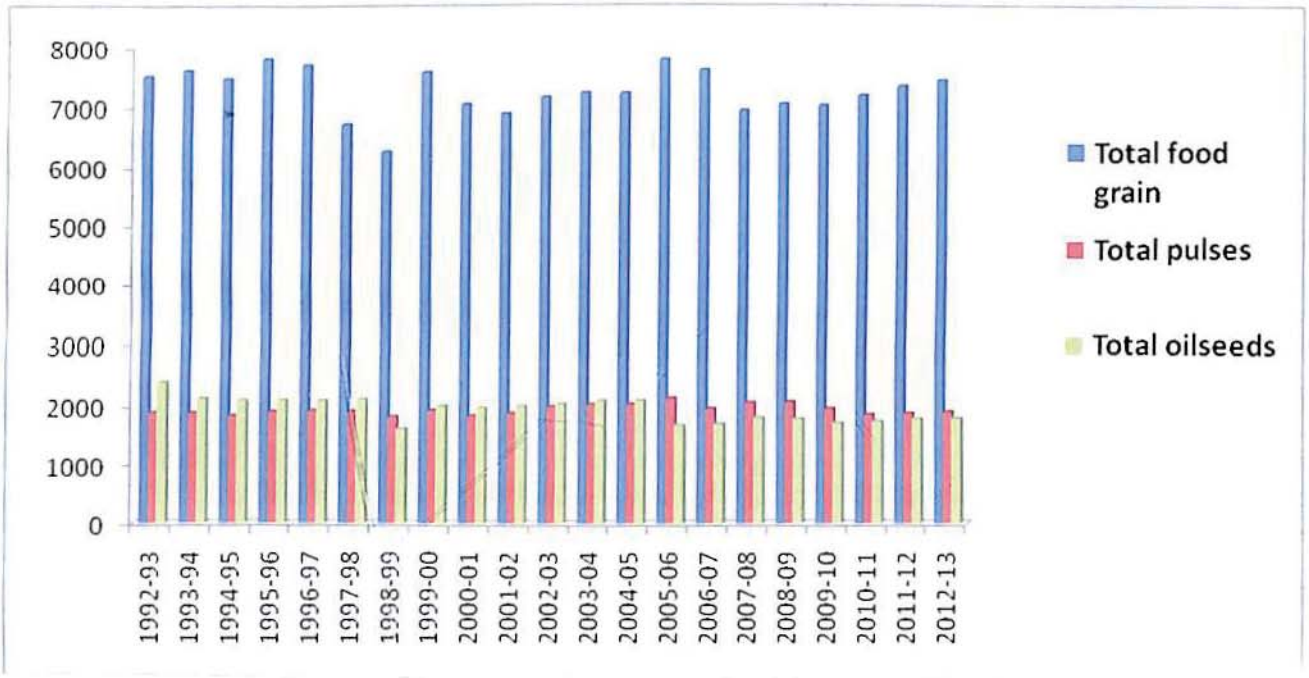
The Government of Sikkim through Department of Agriculture initiated the process of organic farming by tapering off the subsidy in chemical fertilizers @ 10 per cent every year since 2003-04 as the first step. The subsidy was zero from 2007-08. This resulted in drastic decrease in the consumption of fertilizers in the State. The acreage under food grains remained almost constant 71280 ha in 2003-04 to 70120 ha in 2005-06 but showed a sudden rise in 2006-07 and again a fall in 2007-08 while the area under oilseeds remained stable till 2005-06 and showed fall in the subsequent year (Table 4). The fall in area may be attributed to the diversion to developmental work. The production and productivity of all the crops showed marginal increase during the first two years of the conversion period and third year showed even better performance. The marginal increase in the first two years could be attributed to a section of farmers utilizing chemical fertilizers by the time the infra-structure for organic agriculture was readied. The higher jump in 2005-06 was on the expected lines being the third year of conversion by when the crops tend to respond better under organic sources of crop management. The increase in productivity of food grains was 26 and 76.54 kg/ha in 2004-05 and 2005-06, respectively over the previous years' whereas the rise in productivity of oilseeds was 20 and 28 kg/ha in the corresponding periods (Anonymous, 2008).

Table 4. Area (1000 ha), production (1000 tonnes) and productivity (kg/ha) of field crops of Sikkim from 2003-04 to 2005-06 during 'organic conversion period'

Crop	Particulars	2003-04	2004-05	2005-06	2006-07	2007-08
Cereals						
Maize	Area	36.70	36.71	36.70	40.85	39.10
	Production	57.05	58.16	61.10	64.89	62.56
	Productivity	1554.50	1585.00	1664.85	1588.49	1600.00
Rice	Area	14.74	14.74	14.74	14.15	14.00
	Production	21.19	21.61	22.69	21.45	22.85
	Productivity	1437.58	1466.00	1539.35	1515.90	1632.14
Wheat	Area	5.74	5.74	5.74	6.38	4.45
	Production	8.09	8.25	9.20	10.36	4.46
	Productivity	1409.41	1437.00	1602.79	1623.82	1002.25
Finger millet	Area	4.15	4.15	4.15	4.14	3.76
	Production	3.57	3.60	3.78	3.90	3.53
	Productivity	860.24	867.00	910.84	942.03	938.83
Barley	Area	1.23	1.23	1.23	1.15	0.71
	Production	1.51	1.52	1.59	1.27	0.66
	Productivity	1227.64	1235.00	1292.68	1104.35	929.57
Buckwheat	Area	2.01	2.01	2.01	2.04	2.04
	Production	1.55	1.56	1.64	1.79	1.79
	Productivity	771.14	776.00	815.92	877.45	877.45
Pulses						
Urd	Area	3.78	3.78	3.87	3.55	3.55
	Production	2.81	2.84	2.98	2.78	3.11
	Productivity	743.39	751.32	770.03	783.10	875.21
Other pulses	Area	2.93	2.93	2.93	2.41	2.51
	Production	3.57	3.60	3.78	2.67	2.78
	Productivity	1218.43	1228.66	1290.10	1107.88	1107.57
Total Food grain	Area	71.28	71.28	71.37	74.67	70.12
	Production	99.34	101.17	106.76	109.11	101.74
	Productivity	1393.66	1419.33	1495.87	1461.23	1450.90
Oilseeds						
Rapeseed and mustard	Area	6.00	6.00	6.00	5.28	5.00
	Production	4.23	4.28	4.50	4.06	4.32
	Productivity	700.00	713.00	750.00	768.84	864.00

Soybean	Area	3.89	3.89	3.89	3.69	3.60
	Production	3.21	3.25	3.40	3.23	3.15
	Productivity	825.19	835.00	874.04	875.33	875.00
Other oilseeds	Area	0.06	0.06	0.06	-	-
	Production	0.03	0.03	0.05	-	-
	Productivity	500.00	500.00	833.33	-	
Total oilseeds	Area	9.95	9.95	9.95	8.97	8.60
	Production	7.47	7.56	7.95	7.29	7.47
	Productivity	750.75	770.00	798.00	812.71	868.60

The trend of food grain and oil seed production during last 20 years is shown in the table at *Annexure I* and the histogram is given below. There is a rise in the food grain production 2006-07, during that period farmers were using chemical fertilizers in combination with organic sources of nutrients (INM). With the withdrawal of subsidy in chemical fertilizers and due to diversion of agriculture land to developmental work the production drastically reduced, and thereafter, there is a continuous rise in the production of food grains 2007-08 onwards (please see the graph below).



Present soil health status

The evaluation of soil fertility is being done by analyzing the soil samples and the reports show that with the continuous use of organic sources of nutrient there is improvement in the soil health. Soil samples collected from different areas which are under the process of Organic Certification were analyzed for various soil parameters. While comparing the reports for last two years (2011-12 and 2012-13), it was observed that there is an increase in the various soil parameters under continuous utilization of integrated use of organic sources of nutrients.

The percentage of soils falling under the low range of major nutrient contents has reduced while that in higher range has increased. This showed that the maximum number of soil samples tested contain high quantity of major nutrients (NPK). The OC content of the maximum number of soil is high and the pH of the soil has shifted from strongly acidic to medium range.

Fertility Status of Soils of Sikkim

Content	Low Range (2011-12)	Low Range (2012-13)	Medium Range (2011-12)	Medium Range (2012-13)	High Range (2011-12)	High Range (2012-13)	Total (2011-12)	Total (2012-13)
N (kg/ha)	1508 (10.01 %)	1109 (< 280) (5.2 %)	12988 (83.8 %)	16587 (280-560) (78.7 %)	1038 (6.72 %)	3376 (> 560) (16.02 %)	15614	21,072
P (kg/ha)	549 (3.21 %)	289 (<10) (1.3 %)	10,333 (66.17 %)	6103 (10-24.6) (28.9 %)	4732 (30.32 %)	14680 (> 24.6) (69.6 %)	15614	21,072
K (kg/ha)	1536 (9.83 %)	235 (< 108) (1.1 %)	10,837 (69.4 %)	6247 (108-280) (29.64 %)	3241 (20.77 %)	14590 (> 280) (69.2 %)	15614	21,072
Organic carbon (%)	178 (1.14 %)	169 (< 0.5) (0.80 %)	2345 (15.07 %)	3894 (0.5-0.75) (18.49 %)	13,082 (83.79 %)	17009 (> 0.75) (80.7 %)	15614	21,072
pH	3145 (20.14 %)	512 (< 5) (2.4 %)	10,389 (66.53 %)	16313 (5-6) (77.4 %)	2080 (13.33 %)	4247 (> 6) (20.14 %)	15614	21,072

Values in parentheses are sufficiency/deficiency ranges

Wealth of indigenous technical knowledge seemingly exists in Sikkim that needs urgent documentation and validation. After validation some of the indigenous technologies may offer solutions for the gaps in nutrition and/or crop protection. Nevertheless, technologies developed must reach the farmers through an effective transfer of technology mechanism; the KVKs in all districts will perform this crucial function. Organic farm fresh products in a mountain state always face the danger of failure of finding the right kind of marketing through inaccessibility, poor communication and dicey road network. Two options can be resorted to (i) organize self-help groups specialized in marketing and (ii) marketing of value-added organic products through quality post-harvest technologies, which is existing in Sikkim but requires product-based up-gradation. Another area that will reap better returns to the beleaguered mountain farming communities' is market intelligence. Demand-driven cluster-village based cultivation of remunerative crops will strengthen the mountain economies. The Sikkim Organic Mission, Government of Sikkim has its targeted task of full conversion to organic that will be addressed at the state level by 2015.

Activities towards conversion to organic systems

Vermicompost produced by farmers

Vermicompost unit

Rural compost unit

Low cost vermicompost unit

Azolla pond

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