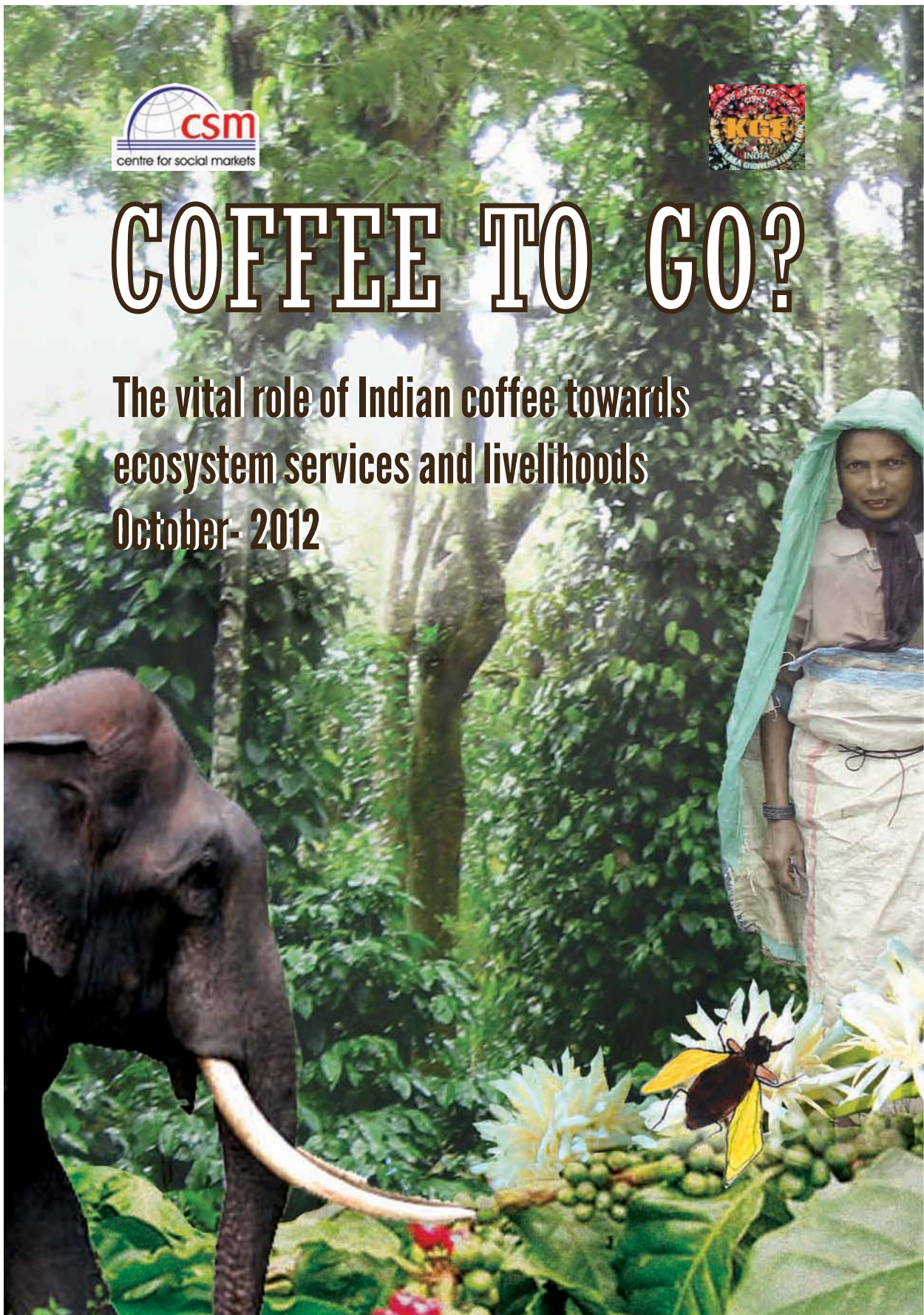




COFFEE TO GO?

**The vital role of Indian coffee towards
ecosystem services and livelihoods
October- 2012**





First published in **October 2012**
United Nations COP-11 CBD Edition

Published by

Centre for Social Markets

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Richmond Town, Bangalore 560 025,
India

Tel: + 91 80 40918235

Website : www.csmworld.org

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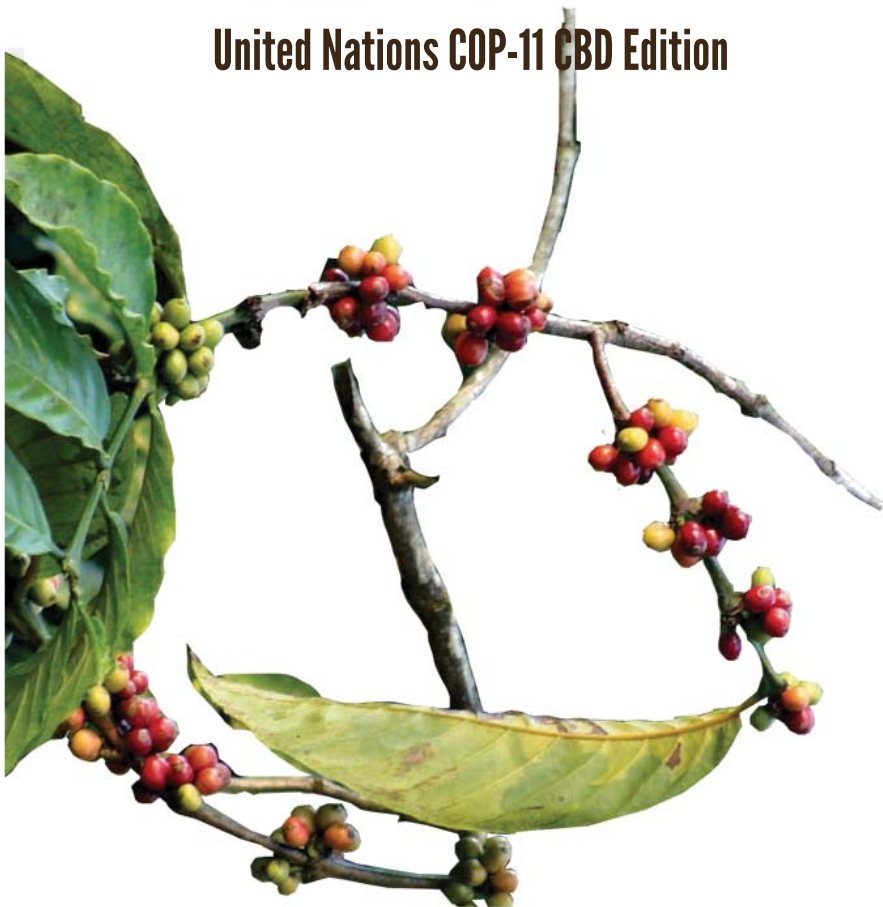
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For more information on this report

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CONTENTS

PARTNERS	1
ACKNOWLEDGEMENTS	2
FOREWORD	3
CHAPTER 1	
INTRODUCTION	6
CHAPTER 2	
OVERVIEW OF COFFEE CULTIVATION IN KARNATAKA	12
CHAPTER 3	
STATUS OF BIODIVERSITY AND ECOSYSTEM SERVICES IN COFFEE PLANTATIONS	20
CHAPTER 4	
COFFEE CULTIVATION IN KARNATAKA ANALYSIS OF EIGHT COFFEE ESTATES FROM 1999 TO 2011	44
CHAPTER 5	
COFFEE CULTIVATION IN KARNATAKA IMPLICATIONS FOR LIVELIHOOD AND BIODIVERSITY	20
CONCLUSIONS AND RECOMMENDATIONS	25
REFERENCES	52

A Pioneering Partnership

In order to assess the extent of contribution of coffee growing practices of Southern India to ecosystem services and biodiversity, the Centre for Social Markets (CSM) and Karnataka Growers Federation (KGF) have convened a team, on behalf of the farmers and coffee plantation owners of the region, of the world's leading practitioners in the economic valuation of natural resources, entrepreneurship and coffee productivity and research.

Centre for Social Markets (CSM)

CSM is an independent, non-profit organization promoting entrepreneurship for the triple bottom line – people, planet and prosperity. This study and report are being commissioned by CSM as part of its programme to promote sustainability and resilience in the Indian coffee sector in the face of multiple challenges. In partnership with KGF, CSM is interested in understanding the contribution of existing coffee farming practices to ecosystem services in forested areas and local economic development.

Karnataka Growers Federation (KGF)

KGF represents the coffee farmers across three districts of Karnataka and their initiative to assess the environmental linkages of their coffee in the context of climate change and the sensitive ecosystem they inhabit. KGF was formed out of the necessity of smaller growers associations joining together to have strength to make their voices heard at the national level. Its mandate is to provide increasing knowledge and capacity building among the growers. Wanting to conduct a scientific, empirical study to demonstrate the multiple benefits provided by coffee growers to the larger community, KGF partnered with the Center for Social Markets (CSM) to estimate the true economic value of shade-grown coffee. KGF brings a valuable ability to disseminate the findings of this study and transcend the results into practical actions with the capacity to mobilise and reach more than a million people in the region.

GIST Advisory

Led by Pavan Sukhdev, author of the UN study, The Economics of Ecosystems and Biodiversity (TEEB), GIST Advisory is a consultancy that assists governments in establishing systems for calculating the real value of ecosystem services and biodiversity for local communities and incorporating the value of nature into decision-making. GIST is the lead research partner in the study and its role is to highlight the economic value of shade-grown coffee in representative farms of Karnataka. It also seeks to explore potential or real impacts to local biodiversity and human welfare from climatic impacts and deforestation activities.

Central Coffee Research Institute (CCRI), Chickmagalur District

A premier coffee research institute in Asia and under the wing of Coffee Board of India, CCRI is striving to evolve strategies aimed at increasing productivity and improvement in the quality of coffee of India. CCRI is instrumental in providing the ground level data for the study. Support has also been received by Coffee Board of India.

Café Coffee Day (CCD)

A division of India's largest coffee conglomerate, the Amalgamated Bean Coffee Trading Company Limited (ABCTCL) Coffee Day is Asia's second-largest network of coffee estates (10,500 acres) and 11,000 small growers. Started in 1996 in the city of Bangalore, today it is the largest organized retail cafe chain in the country. CCD has been a knowledge partner in this study.

ACKNOWLEDGEMENTS

The Center for Social Markets (CSM) and Karnataka Growers Federation(KGF) would like to thank the following for their support in making this report possible.

Kaavya Varma, Prof Lalit Kumar , Sanjib Jha , Nachiketa Das and Dhaval Negandhi from GIST Advisory Services for preparing the report

Jawaid Akhtar, The Chairman, Coffee Board, for his support to this study

Dr.Raghu Ramalu , Joint Director, Central Coffee Research Institute

Mr.H.R.Basanna, Mr. Mohan Kumar, Secretary of KGF, Mr. Teerthamallesh Treasurer, KGF

Mr.Y.S.Girish

Dr. Anand Titus Pereira

The office staff at Karnataka Growers Federation (KGF) and all its members

The President and members of Hassan District Planters' Association and all the Taluks , hoblis and associations of KGF

Anshu Ogra of JNU (Centre for Studies in Science Policy)

Krushika Team at Chikmagalur District

Suresh Chandra Dutta ,an avid photographer and also a coffee farmer, for providing the photopragphs for this report

Dr Kushalappa and his team at The Forestry College, Ponnampet , Kodagu , for their initial guidance

Thara Thomas (design)

Jwalamukhi Mudranalaya Private Limited, Bangalore (Printing)

The team also acknowledges the invaluable insights and feedback from Pushpanath Krishnamurthy of Oxfam, GB, Dr Pradeep, President of KGF and Viva Kermani of CSM

How we brewed 'Coffee To Go'

This explorative study is the first of its kind on coffee in India. It emphasises the link between the economic and ecosystem values of coffee production. A link upon which depend the livelihoods and interests of more than one million workers and 150,000 growers. A cultivating community that produces India's unique shade-grown coffee under the forest canopy of more than 60 million trees, contributing simultaneously to tending a natural ecosystem and growing a unique economic asset.

The story of coffee in India (about 70% comes from the southern state of Karnataka) is the story of the small farmers (98.8 % of coffee farmers own small holdings) and the inspiring breadth of their vision. They grow their coffee under two tiers of shade, the forest canopy of the Western Ghats, a treasure trove of biodiversity and the water tower of peninsular India, a hill chain originally recognised as among the several global 'hotspots of biodiversity'.

Coffee is the world's most widely traded tropical agricultural commodity and yet the singularly ecological growing practices of Indian coffee are but a little-known aspect of this globally popular beverage. The coffee beans of the districts of Kodagu, Hassan and Chikmagalur share their air and nutrients with other plants, vegetation and wildlife in a concert that contributes to biodiversity conservation, protects watersheds, generates rural livelihoods and soaks up greenhouse gas emissions.

As this study signals, coffee agro-forest systems can substantially aid in reducing the intensity of physical damages to the ecosystem by providing an alternative habitat to local biodiversity, and also by serving as a source of ecosystem services that are generally provided by natural forests. Our farmers and growers are willing and committed custodians of the richness of the Western Ghats – their coffee-growing practice helps prevent soil erosion, conserves the water that peninsular India thirsts for, maintains wildlife corridors, sequesters carbon and provides dependable livelihoods that feed into local socio-economic development.

The critical analysis found in this exploratory study – which scrutinises the linkages between coffee agro-systems and the extent of their impacts on ecosystem services – has come at a turning point for India's coffee farmers and growers, for they are experiencing ever more frequently the effects of destabilising climate change. This change is affecting coffee production in India, and is causing the degradation of the invaluable ecosystem services provided by the shade-grown coffee cultivation practice. Just as the small coffee farmers deserve recognition of (and support to) their unique role in biodiversity conservation, so too do they need the outcomes from a partnership such as this which aids them in their efforts to adapt to a changing climate.

This is the central message of 'Coffee To Go', the result of a partnership which will undertake further research in the main coffee-growing districts of South India to capture the impacts of climate change on the coffee production of small and medium producers over the last decade. The strengths and synergies of this partnership reposition the Indian coffee farmer as a student

of the risks that climate change has brought into their green hills, and who rises to the challenge by being steadfast towards biodiversity protection, thereby ensuring the real benefits of conservation and traditional coffee farming practices to local communities as they confront a climate and resource-constrained world. It is part of a broader multi-stakeholder Sustainable Coffee Initiative started by CSM and KGF in 2011 which involves leading private sector, academic, governmental and non-governmental partners.

Viva Kermani
Chief Operating Officer
Centre For Social Markets

Dr Pradeep Nandipur
President
Karnataka Growers Federation







Coffee is the world's most valuable agricultural commodity and the ubiquitous cup of coffee is characterized by massive economies of production, consumption and trade.

The coffee plant is a woody perennial dicotyledon of the genus *Coffea* (*Rubiaceae*) consisting of over 80 species; out of which only two species are important for production of coffee beans – Arabica (*Coffea arabica*) and Robusta (*Coffea canephora*). Characterised by a complex value chain and despite rapid rise in retail prices and economic turmoil; in 2011, the value of global coffee exports touched the US\$ 24.9 billion mark (ICO 2012).

Globally, the coffee industry employs around 25 million farmers – mostly smallholders – in over 50 developing countries (IBRD 2004) and historically coffee exports have been linked to the development 'success' stories of Brazil, Colombia and Costa Rica. As of 2010, coffee exports accounted for over 10 per cent of total foreign exchange earnings for several African and Latin American developing countries including Burundi, Ethiopia, Rwanda, Uganda, Nicaragua, Honduras and Guatemala. With the emergence of large actors in the global coffee value chain and increasing productivity; global coffee prices have averaged a 3 per cent per year decline for Arabica and 5 per cent for Robusta, since 1970. This has culminated in significant socio-economic disturbances such as high labour displacement, worsening poverty, balance of payment problems and lost revenues across coffee producing countries based upon prevailing industry structures in each (*ibid*).

The crop's susceptibility to climatic disturbances, such as increase in temperatures and extreme rainfall events, is being compounded by the emerging paradigms of coffee production that diverge from traditional shade-grown biodiversity-friendly coffee agroforestry management practices – including more fertiliser and pesticide use, non-shade farming and intensification. The inherent linkage between biodiversity and ecosystems services (BES) and coffee cultivation has a vital role in the commodity's future; including permanent impact on the livelihoods of the millions who depend on it.

Discovery of the bean

Coffee, as the popular legend goes, was discovered sometime around 800 A.D. when an Ethiopian goatherd named Kaldi noticed that the goats of his herd became abnormally frisky after consuming the cherry-red berries from a certain shrub (Taylor 1965). Intrigued, the goatherd tried some of the berries himself and later passed on the berries to the abbot of a local monastery, who discovered that it enabled him to remain alert even after the long evening prayer. Passing from the abbot to other monks and monasteries, the knowledge of the berries began to spread east and eventually reached the Arabian Peninsula. Coffee beans were first roasted and brewed in Arabia in 1000 A.D., and by the 13th century coffee drinking had become an integral part of Islamic culture; spreading along with Islam to North Africa, eastern Mediterranean and India. As a result of the strict regulation of monopoly of the bean; the concentration of coffee production was limited to Africa and Arabia until the 1600's (National Geographic Society 1999).

The journey out of Arabia

Coffee made its appearance in India in the 16th century from the Yemeni port of Mocha, carried by the Muslim saint Baba Budan (Ukers 1935). Planted in the hills of the Western Ghats, coffee cultivation was soon embraced by several indigenous and ethnic tribes of the region. From there, coffee travelled to South-East Asia, when the Dutch founded the first European-owned coffee estate in Java, Indonesia, in 1669. Passing from the hands of the Dutch, in 1714, the coffee sapling travelled to France and to the court of Louis XIV and from there



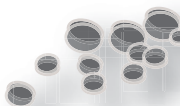
to the hands of a young naval officer named Gabriel Mathieu de Clieu, who brought it to the Latin American island of Martinique. In 1727, the Brazilian government obtained its first coffee seedlings from Martinique. Taking instantly to the climate, Brazilian coffee production yielded huge harvests and by the second half of the 19th century coffee production had expanded throughout the most important agricultural areas of Brazil (Monaco, L.C., 1977).

Current state of coffee cultivation in India

Post-independence, coffee emerged as an important export commodity for India, and currently India accounts for 4.5 per cent of the global coffee production. In 2011, India exported a total of 344,606 tonnes of coffee (including re-export), earning a foreign exchange of US\$ 1048.5 million (Coffee Board, 2012).

The traditional coffee growing areas of India comprise of Karnataka, Kerala and Tamil Nadu, with Andhra Pradesh, Orissa and the North Eastern Region constituting the non-traditional areas. From 1950 to 2012, the total area under coffee cultivation in India has increased from 92,523 hectares to over 409,690 hectares, with Karnataka accounting for around 229,658 hectares (56.1 per cent) of the total area and 226,335 million tonnes (70.7 per cent) of total national production (Coffee Board, 2012).

Although India is the only country that grows all its coffee under shade (*ibid*), by



retaining the traditional practice of cultivating coffee under a three-tiered canopy; the expansion of coffee cultivation in the 1970's and 1980's took place at the expense of native vegetation cover (Garica et al., 2007) and has been associated with the trend of replacing native shade trees with the exotic Silver Oak (*Grevillea robusta*) due to economic pressures discussed in subsequent chapters of this report. There has been a marked by a shift from Arabica to Robusta cultivation over the years, with the area under Arabica cultivation declining from 73 per cent of total area under coffee cultivation to 49 per cent, and Robusta cultivation increasing from 27 per cent to 51 per cent to total area, from 1950 to 2012 (Coffee Board, 2012).



A critical link between coffee and ecosystems

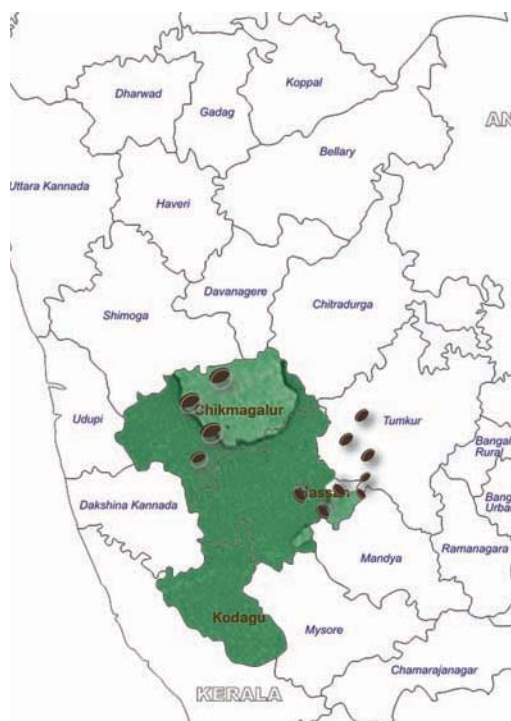
Human activity is unarguably the most important factor in contemporary alteration of natural landscapes (Morris, 1995). However mosaic habitats such as traditional coffee agro-forests are less susceptible to physical changes, especially when of reasonable size and proximity to natural forests. This is evident by the fact that the tree, bird and fungal diversity in coffee plantations in Kodagu were comparable between adjacent protected forest and sacred groves (Bhagwat et al., 2005). As a result coffee agro-forest systems can aid in effectively reducing the intensity of physical damages to the ecosystem by providing alternative habitat to local biodiversity and source of ecosystem services generally provided by natural forests, including prevention of soil erosion, water sequestration, wildlife corridors, carbon sequestration and livelihoods for the poor.

Intended as a purely scoping study, this report undertakes a critical analysis that considers the inter-linkages between coffee agro systems and the extent of their impacts on ecosystem services, with a particular focus on carbon. The long-term effects of climate change through variability in rainfall and underground water levels and their impacts on coffee growing practices in Karnataka are further taken into account. This is vital as a positive correlation between the existing farming practices on the plantations of the Karnataka Growers Federation and the ecosystem they inhabit is globally significant, as it could represent a best-practice example of coffee farming with low impacts on ecosystem services and biodiversity; a relationship that would then need to be preserved, scaled and replicated.





Chapter 2: Overview of Coffee Cultivation in Karnataka



Trends in coffee production and rationale for study

India is the fifth largest coffee producer in the world, with 2 per cent of global area under coffee contributing to around 4 per cent of global coffee production. Important varieties of coffee grown in India include Kents (an early variety of Arabica noted for its exceptional cup quality); S.795 (a high yield Arabica noted for its superior cup quality and tolerance to leaf rust); Cauvery (an Arabica descendent incorporating the superior quality of *Caturra* and resistance of *Hybrido-de-Timor* variety); Sln.9 (an award winning Arabica variety that inherits the superior cup quality of Tafari-kela); S.274 (an improved variety of Robusta) and CxR (a hybrid of *Congensis* and Robusta). Acclaimed for the unique flavour of its berries and plantation biodiversity; coffee cultivation in India encompassed an area of over 409,690 ha and generated a yield of over 314,000 MT, in the year 2011-2012 (Coffee Board, 2012). More recent trends, based on the post-blossom estimates released by the Coffee Board, show that India's coffee output is likely to cross 325,300 MT in the year 2012-2013.



Traditional coffee growing regions in India constitute of the southern states of Karnataka (229,658 ha), Kerala (84,948 ha) and Tamil Nadu (31,344 ha). Together they represent over 84.5 per cent of total area under coffee cultivation and produce 97.9 per cent of total coffee in India (*ibid*). Karnataka alone accounts for over 56.1 per cent of total area under coffee cultivation and over 70.4 per cent of total coffee production in India – making it the most significant coffee producing state of the country.

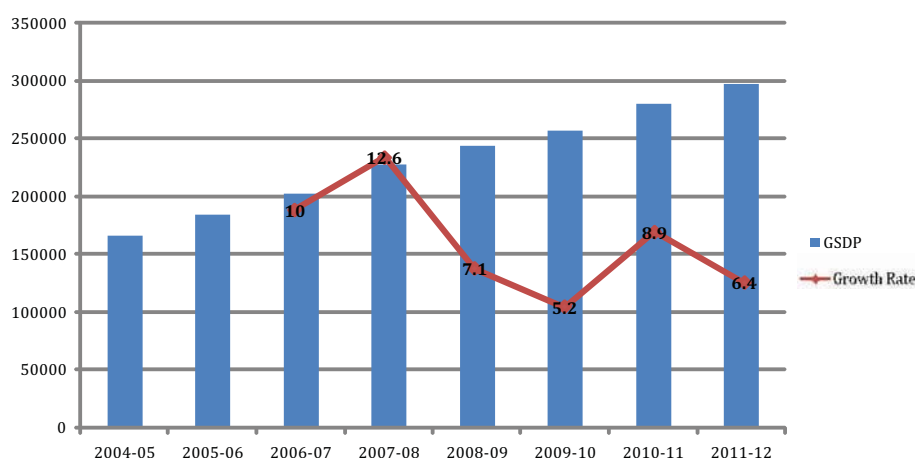
A global coffee supply deficit caused by frost in Brazil in the mid nineties caused prices to shoot up abnormally and in turn prompted a surge in production that substantially altered the industry production structure (Venkatachalam, L., 2005); leading to a surge in growth of Indian coffee production, in the early part of 2000. But, with production increasing at an average annual rate of 3.6 per cent, compared to demand increasing only by 1.5 per cent; global coffee prices fell substantially touching a 100-year low in 2004-2005 (ICO 2002). Stranded with increased costs of production, many growers – especially small and medium landholders – were heavily indebted, and many not having recovered were forced to switch to other crops or sell their estates.

Composition of Karnataka's Economy

Bordering the Arabian Sea to its west, Karnataka covers an area of 191,976 sq. km. or 5.83 per cent of total geographic area of the country; making it the eighth largest state of India. Comprising of a population of over 61.13 million (in 2011) and having a literacy rate of 67 per cent; Karnataka is one of the high economic growth states, with a Gross State Domestic Product (GSDP) growth of 8.9 per cent (at constant price) in the fiscal year 2010-2011 (CII, 2012). The average GSDP growth rate between 2005-2006 and 2011-2012 is about 8.36 per cent

(see Figure.2.1); with the Primary Sector contributing 17.24 per cent of total GSDP for the year 2011-2012.

Figure.2.1. Karnataka GSDP and Growth Rate at 2004-2005 prices (in ` Crores)



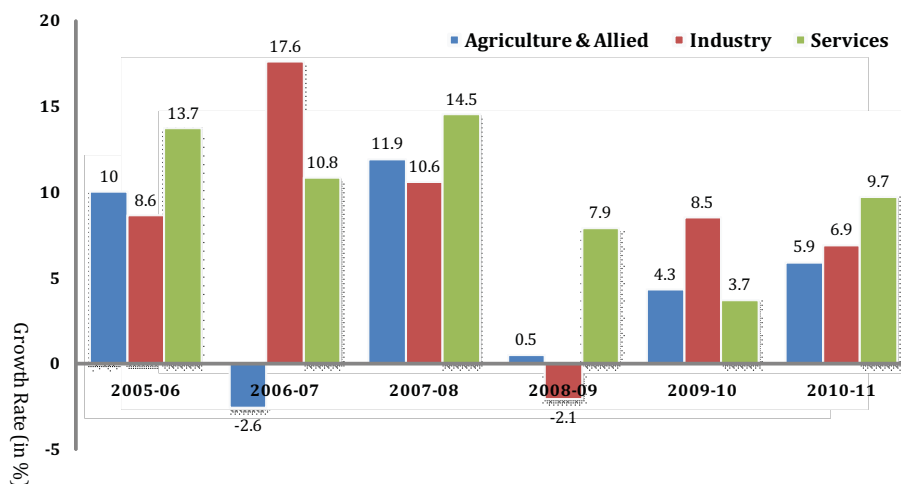
Source: Compiled from Central Statistical Organisation (CSO) (As on 01.03.2012)

Karnataka is the manufacturing hub for many of the largest public sector industries in India, including Hindustan Aeronautics Limited, National Aerospace Laboratories, Bharat Heavy Electricals Limited, etc. and houses various premier science and technology research centres including Indian Space Research Organization, Central Power Research Institute, Bharat Electronics Limited and the Central Food Technological Research Institute. The state is well known for its knowledge-based industries such as IT, biotechnology and engineering, with IT and ITes exports valued at US\$ 16.3 billion, in 2008-09 (*ibid*).

Out of the 17.24 per cent contribution of the Primary Sector to state GSDP, agriculture accounts for 13 per cent of the total GSDP (Government of Karnataka, 2011). Over 123,000 sq km of land is under cultivation; constituting 64.6 per cent of the total geographical area of the state (Government of Karnataka, 2006). Since 2005, the agricultural sector has suffered from wide variations in annual growth rate over the previous years, including negative growth in the year 2006-07 due to drought (see Figure.2.2). Despite such volatility, Karnataka is the largest

producer of coffee, raw silk and coarse cereals among Indian states, with horticulture constituting over 40 per cent of income generated from agriculture in the state (CII, 2012).

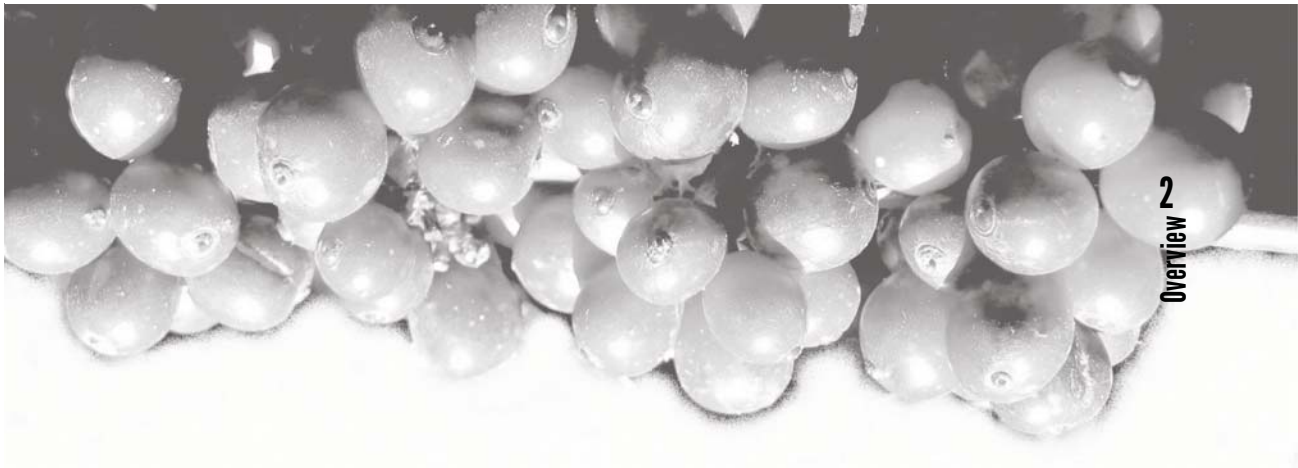
Figure.2.2. Annual sectoral growth rate, Karnataka (2005-2011)



Source: Economic Survey of Karnataka 2010-2011

Coffee Cultivation Practices in Karnataka

Coffee cultivation in India is said to have begun in the 16th century when the saint Baba Budan planted the first seven beans in the Chandragiri hills of Karnataka. Extensively incorporated in the local culture, traditional coffee growing practices included a well-defined two-tier mixed shade canopy comprising of evergreen leguminous and native trees. Traditional cultivators also grew a wide variety of spices and fruit as auxiliary crops such as pepper, cardamom, vanilla, orange, banana and areca nut intertwined in the shade canopy. The traditional coffee agroforestry system developed and sustained by cultivators in Karnataka is one of the most diverse production systems in the world; involving a unique cultivation method utilising the shade of natural tree cover without negatively impacting the local forest ecosystem. Coffee plantations under such agro forestry system sustain biodiversity in the form of flora and fauna and in turn contribute to valuable ecosystem services in terms of hydrological services and carbon sequestration (CAFNET, 2011).



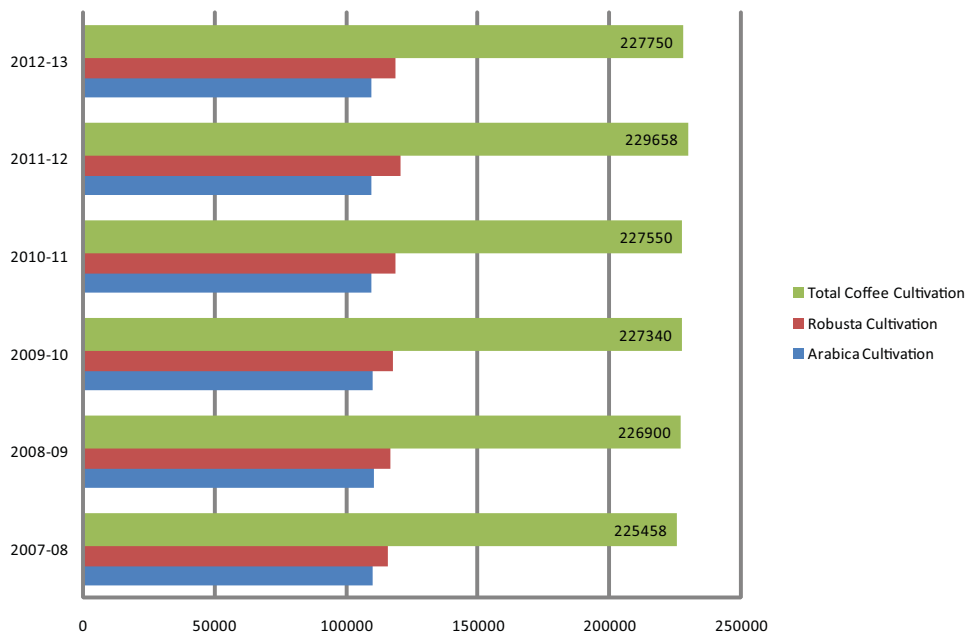
Coffee cultivation is a laborious and costly process. Beginning with the selection of a site for a plantation, to choosing the right variety of coffee suitable to the climatic and topographical features of the selected location, to preparation of the land for cultivation and maintaining the soil properties ideal for coffee; there are several requirements that must be fulfilled precisely in order to obtain a successful harvest. In general, coffee plantations in Karnataka (and rest of India) are located on gentle to moderately sloped land at an elevation of 1000-1500 meters above mean sea level (MSL), with a cool equable climate of 15-20° C for Arabica and 500-1000 meters above MSL, with hot and humid climate of 20-30° C for Robusta. The land is divided into blocks of convenient size by laying out footpaths and roads in between and the bush undergrowth on the ground is cleared by uprooting and in situ burning; while maintaining the top canopy of permanent shade trees and a lower second and temporary canopy of trees such as Dadap (*Erythrina lithosperma*) (Pradeepkumar, T., et al., 2008).

In 2011-2012, coffee plantations covered an area of 229,658 ha (109,128 ha of Arabica cultivation and 120,530 ha of Robusta cultivation) in Karnataka (see Figure.2.3); with a corresponding production of 221,000 MT of coffee (79,825 MT of Arabica and 141,175 MT of Robusta). Overall, the state produces 70.4 per cent of total coffee in India, including 25.4 per cent of Arabica and 45 per cent of Robusta of the country (Coffee Board, 2012). According to estimates, the share of coffee as a percentage of agricultural output in individual district's GDP is quite significant, with coffee cultivation accounting for 29.48 per cent of the agricultural output of Chikmanglur; 45.36 per cent of agricultural output for Kodagu; and 12.65 per cent of agricultural output for Hassan.

With an expansion in coffee planting and bearing area, the traditional coffee growing areas have reached a plateau and further expansion is mostly in non-traditional areas; forcing traditional coffee growing regions like Karnataka to

increase productivity gains and economise on the cost (Venkatachalam, L., 2005). With global commoditisation of coffee, traditional landscape systems such as rice paddies with adjoining domestic forests are becoming less valuable, and over the last 40 years many have been converted into coffee estates (Garcia et al., 2007).

Figure.2.3. Total area under coffee in Karnataka



Source: Compiled from Coffee Database 2012, Coffee Board of India

The last few decades have witnessed a fundamental shift in the characteristic of coffee holdings in Karnataka. As a result of easier management, better pest-resistance and large scale development of irrigation systems most estates, which previously cultivated Arabica coffee under a dense mixed cover of native shade, are being converted into Robusta coffee, which requires sparse shade (Garcia et al, 2009). However, in current scenarios where canopy cover is reduced and the need for artificial interventions has increased, the advantage with Robusta, is that it requires less pesticides relative to Arabica. Tree composition of coffee agro forests are also being affected by changes in management practices such as drip irrigation for stimulating mass flowering of coffee and increased use

of pesticides and fertilisers in some cases. Due to the long gestation between replanting of coffee saplings and production of cherries; many cultivators are forced to supplement their income by harvesting timber from their estates. Although the loss of native trees is being compensated by planting greater number trees, including the fast-growing exotic Sliver Oak (*Grevillea robusta*); this has resulted in a decrease in canopy cover and the population of native tree species in some estates.

Summary

With the global coffee industry having undergone a transition in the latter half of the preceding century, marked by an increase in coffee production at the cost of the environment in major producing countries such as Brazil and Vietnam; the case for eco-friendly practices and biodiversity conservation potential of Indian, especially Karnataka's, coffee agroforests is growing. With consumers across the globe becoming increasingly conscious of the need to recognise conservation efforts at a local level and willing to pay for such; there is a real opportunity for Karnataka's coffee growers to avail of economic benefits by capitalising on the environmental and livelihood benefits of their traditional practices.





Chapter 3: Status of Biodiversity and Ecosystem Services in Coffee Plantations



Coffee cultivation in Karnataka is centred in the Western Ghats region – one of the biodiversity hotspots of the world – by interspersing coffee within the native forests.

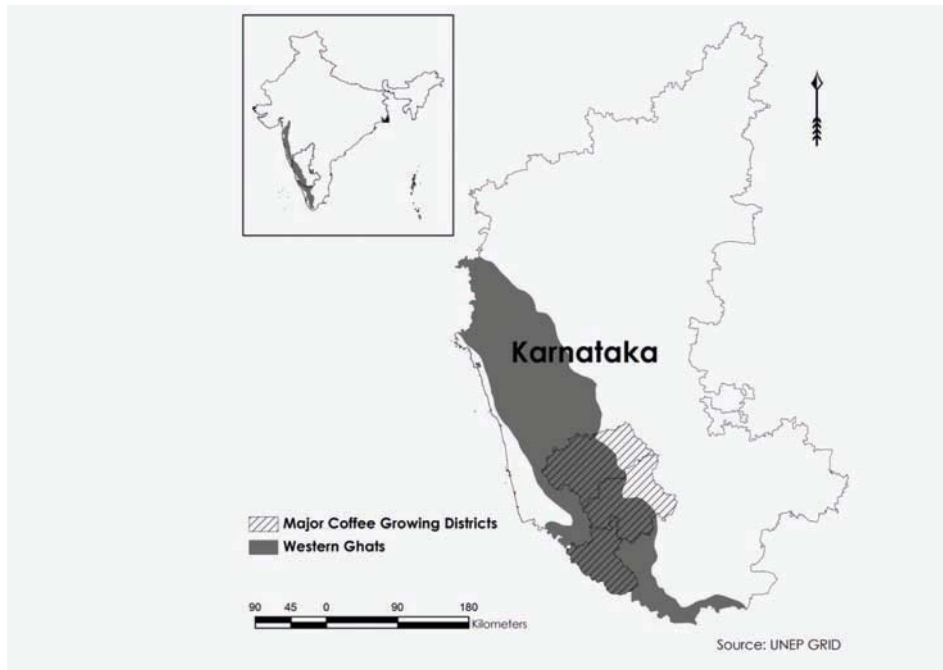
Western Ghats comprise of over 160,000 sq km, of which 31,514 sq km are located in Karnataka, and play a crucial role in the rainfall spell of Peninsular India by intercepting the south-western monsoon winds. The birthplace of eastward flowing rivers, such as the Cauvery, that sustain over 245 million people dependent on these river systems in the region; the Western Ghats are home to 139 species of mammals, 508 species of birds and 179 species of amphibians (Rao, V.S., 2012).

The Western Ghats – Global Biodiversity Hotspot

The Western Ghats are amongst the oldest tropical forest landscapes existing even today. Human activity in the Western Ghats, mostly in the form of hunting and gathering, dates back over 12,000 years (Chandran, 1997), with agricultural landscapes first making their appearance over 2000 years before present (Ranganathan et al., 2008).

The Western Ghats are amongst the eight hottest biodiversity hotspots in the world in terms of five factors; the number of endemic plants, endemic vertebrates, endemic plant/area ratio, endemic vertebrate/area ratio and remaining primary vegetation as per cent of original extent (Myers et al., 2000). Over a third of the geographical area of the Western Ghats are covered by forests of various types – from evergreen to semi-green forests, moist forests to deciduous forests – and are home to several endangered species. Out of the 1073 vertebrate species found in the region, 355 are endemic to the region; similarly out of 4780 plant species, 2180 are endemic to the region (*ibid*).

Figure. 3.1. Western Ghats & major coffee growing districts in Karnataka



Source: Self generated from UNEP Grid

Deforestation and biodiversity in coffee agro forest systems in the Western Ghats

Although clear felling and logging were stopped in the early 1980's in the Western Ghats with the enactment of the Forest Conservation Act of 1980; most of the forest areas, including those in Protected Areas (PAs), continue to be under various extractive and non-extractive uses by human communities living within and close to the forests (Daniels et al., 1995; Karnath et al., 2006). Between 1920 and 1990, there was a 40 per cent decline in the forest cover in the Western Ghats, with conversion of forest areas to open or cultivated lands accounting for 76 per cent and conversion to coffee plantations accounting for 16 per cent of this loss (Menon and Bawa, 1997). In addition to outright loss of forest cover, there has been widespread degradation in the form of reduced forest canopies (less than 20 per cent canopy cover) as a result of extractive and non-extractive use of forests (Jha et al., 2000).

Moreover, recent years have seen a major shift in the shade canopy for one that largely resembled traditional polycultures to monocultures of Silver Oak – primarily for economic benefits derived from harvesting of timber (Damodaran, 2002).

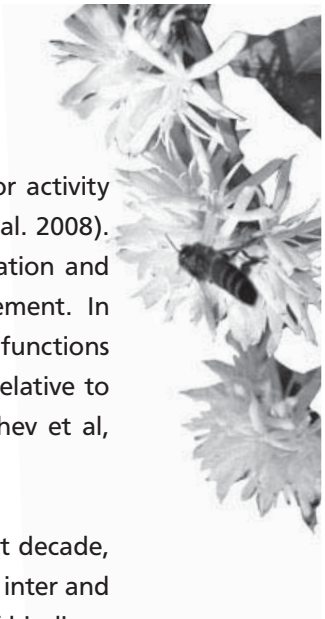
Currently the Western Ghats consist of a protected area (PA) network of 13,595 sq. km. (Critical Ecosystem Partnership Fund, 2007), with plantations of commodity crops covering over 10,000 sq. km. – predominantly in the central and southern regions – including coffee plantations of over 3000 sq. km. This highly fragmented PA network is embedded with structurally complex human-modified landscapes featuring greater habitat heterogeneity, such as coffee agro forests, which also act as secondary wildlife habitats for foraging or as corridors enabling movement between PAs. Such human-modified landscapes are characterised by a high degree of endemism and species richness as a result of highly restricted distribution and small scale species turnover across hill ranges or drainages (Pascal, 1988; Vasudevan et al., 2006). Take for example the newly discovered frog species, *Philautus dubios*, which is presently known to occur only at locations in human-modified landscapes (Biju and Bossuyt, 2006). Given the predicted and documented shift in species distribution in response to global climate change (Parmesan and Yohe, 2003), landscapes between PAs take on increased importance as potential paths for migration of flora and fauna (Donald and Evans, 2006); especially for key species such as elephants, tiger, leopard and gaur. In such a scenario, intensification of coffee cultivation and rapid departure from traditional land use practices may lead to a complete conversion of such landscapes from multi species use to singular human use; resulting in irreversible loss in biodiversity value in the region. Hence, the continuation of such practices by Karnataka coffee growers in the face of economic disincentives, is a highly commendable and extremely important service that must be recognised as such.

Ecosystem services provided by the Western Ghats

Although not much is known regarding the capacity of various coffee systems within the Western Ghats to regulate water balance (infiltration, ground water production), soil erosion, local climate, pollination, soil productivity, etc, but the general view is that high tree cover with a variety of tree species increases the capacity to generate these functions (cf. Steffan-Dewenter et al. 2007). For example, in coffee agro ecosystems ants, birds and bats can control important

coffee pests (Borkhataria et al 2006; Philpott et al 2008) and pollinator activity could increase close to natural forest fragments (Rickets 2004, Klein et al. 2008). Such coffee agro forests cover a gradient of carbon storage, sequestration and evapotranspiration levels depending on shade-practices and management. In general, coffee agro forests are expected to have similar hydrologic functions (green water and blue water flux) and carbon sequestration services relative to native forest types they have replaced (Krishnaswamy et al 2009; Olchev et al, 2008; Kumar and Nair, 2006).

Biodiversity conservation has received considerable attention in the past decade, with research indicating both human and non-human impacts as well as inter and intra generational impacts of biodiversity loss. Although the benefits of biodiversity conservation accrue to the local and global community at large, the costs are most often borne by the local community who depend on forests for various goods and services (Pearce and Moran, 1994; Shyamsundar and Kramer, 1996; Shyamsundar and Kramer, 1997).



Impact of climate change on coffee cultivation

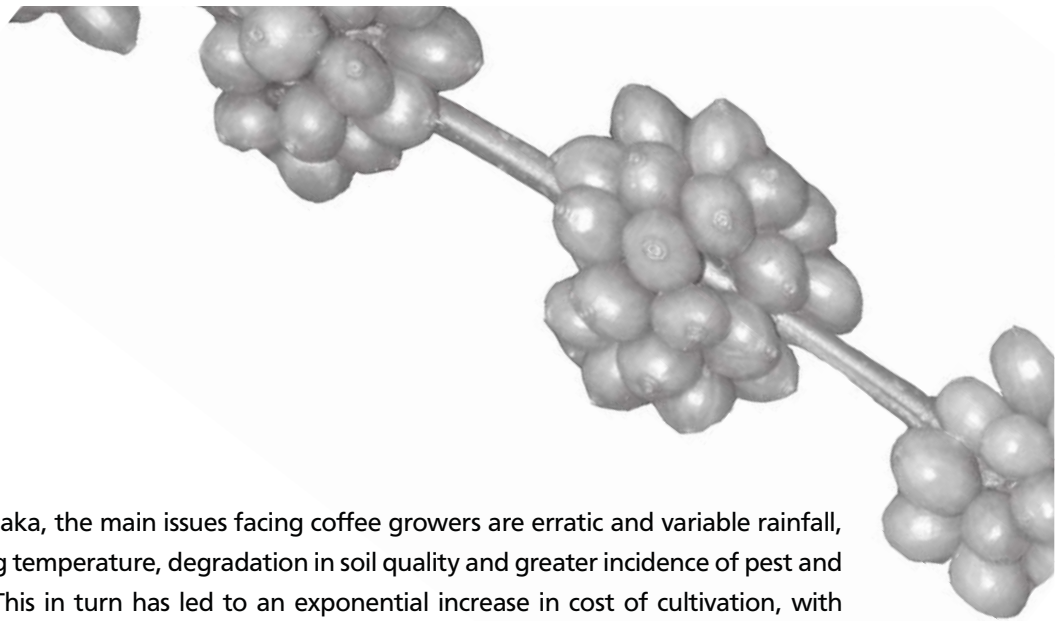
The current changes in global climate are a repercussion of human activities over the past two centuries; most notably the increasing use of fossil fuel and mineralisation of organic matter as a result of land use and resource extraction. The relationship between GHG emissions and increase in global temperature is well documented by science; but what is of even more note is the impact that such climatic changes will have on traditional sectors such as agriculture and the millions of livelihoods dependent upon it. The International Coffee Organisation considers climate change as the most important amongst several factors that may affect global coffee production, with smallholders (who produce most of the world's coffee) being the most vulnerable group (International Trade Centre, 2010). Coffee is noted for being a very difficult crop which requires very specific climatic conditions – with temperature and rainfall conditions being the two main drivers behind yield – and rising temperatures are expected to render certain existing producing areas less suitable or even completely unsuitable for coffee cultivation; resulting in shift in production to alternative crops. Although the complete impact of climate change on coffee cultivation is difficult to predict, a few important long term impacts as noted by the International Panel of Climate Change (IPCC) are as follows:

- **Changes in yield due to changes in seasonal climates, including erratic rainfall**
- **Changes in production potential in relation to factors such as yield, land availability and longer/shorter growing seasons**
- **Crop response to changes in atmospheric conditions**
- **Changes in price and trade patterns due to climate change**
- **Changes in food security and livelihood, i.e., number of people at risk of hunger and poverty**
- **Water run-off and related water stress**

The four major impacts of climate change on coffee production in the short run are

- **The fall in quality of coffee bean**
- **Reductions in yield**
- **Increase in incidence of pests and disease**
- **Increase in irrigation, fertiliser and pesticide costs**

Already extreme climatic events such as the El Nino have had a direct impact on coffee production in Andean countries like Columbia – where during its occurrence rainfall decreases while sun intensity and temperature increase – causing production to fall in low-lying regions with low retention of moisture and high exposure to sunlight, which receive less than 1500 mm rainfall per year. In Nicaragua, climatic variations between El Nino and La Nina have contributed to extreme variations in coffee production, with incomes of small farmers crashing from US\$ 2300 in one year to only US\$ 600 in the next (Hagger, J., 2008). In Brazil, dramatic changes in production and revenue have been predicted as a result of increasing temperatures, with a conservative 1°C increase in temperature reducing production by 80,829 tonnes and revenues by US\$ 113,160,600; and a 5.8°C increase in temperature reducing production by 334,165 tonnes and revenues by US\$ 467,831,000 (Pinto et al., 2007).



In Karnataka, the main issues facing coffee growers are erratic and variable rainfall, increasing temperature, degradation in soil quality and greater incidence of pest and disease. This in turn has led to an exponential increase in cost of cultivation, with farmers becoming more and more dependent on fertilisers, pesticides and irrigation. Many of the small growers are unable to meet the rising production costs and remain in debt – which further affects their capacity to manage coffee cultivation in subsequent years.

Summary

Coffee agro forest systems in Karnataka play a vital role in maintaining the flow of biodiversity and ecosystem services in the Western Ghats region, second only to natural forests. Over the years, traditional coffee cultivation practices have ensured that the biodiversity and ecosystems services value of such agro forests remains intact. But with the rapid transformation of the market and production systems, incentives for maintaining such values are fast eroding as farmers look towards intensification to cover the increasing costs of cultivation. This in turn has real negative impacts on biodiversity via loss in species richness and by exacerbating human-wildlife conflict in the region, as human activity transforms traditional foraging and migratory habitats of native wildlife. Also, the impact of such intensification is evident in the degradation in soil quality via soil runoff and nutrient depletion, which further increases fertiliser costs; and in the increase in incidence of pests and disease and pesticide and maintenance costs associated with preventing it. Coffee agroforests provide key regulating and supporting ecosystem services of which they themselves are main beneficiaries – making them an ideal self-sustaining ecosystem. Hence, it is only prudent that an effort be made to ensure continuation of such services and for reversing any existing declining trends.

Currently conservation priorities in the Western Ghats are more about preventing further loss of existing diversity than reintroducing diversity in agroforestry systems (Garcia et al., 2009). In order to change this, farmers need to be given the choice to join incentive schemes for conserving native habitat within the agricultural matrix, which generates on a timely basis previously defined financial rewards commensurate to opportunity costs incurred.





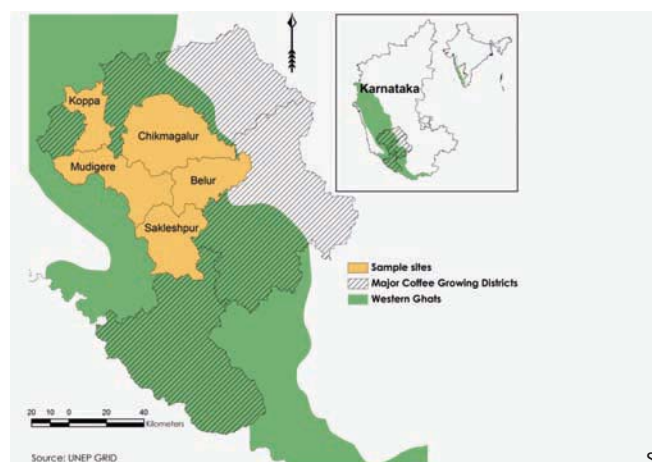
Chapter 4: Coffee Cultivation in Karnataka – Analysis of Eight Coffee Estates from 1999 to 2011

The main motive of the authors is to understand and highlight the linkages between coffee cultivation practices in Karnataka and the continuation of BES services that coffee agroforestry systems provide; allowing for significant economic benefits to both coffee cultivators as well as the population of the region. Although the importance of biodiversity conservation in coffee agroforestry systems has been a focus area for research – backed by substantial amount of literature; the study revealed that there was a clear lack of the same on the provisioning of ecosystem services (ES) in Karnataka. Hence this present analysis is a purely indicative study that takes on the role of laying the foundations for a detailed study in the future.

Coffee estates included in current study

Bound by stringent time constraints and given a lack of exhaustive primary and secondary data sources, our current study is focused on analyzing eight sample coffee estates (each over 100 acres each) chosen randomly from across the districts of Chikmagalur, Hassan and Coorg (Kodagu) (See Figure.4.1 and Table 4.1).

Figure.4.1. Map of coffee estates sites included in study



Source: Self generated from UNEP Grid

Table.4.1. Coffee estates included in study

Name of Estate	Size (Ha)	Location	Ownership	Coffee Type	Specialty
Tirthagundi Estate	80.94	Koppa, Chikmangalur	ABC Ltd.	80% Arabica	80 Years Old
Kudregundi Estate	161.87	Mudigere, Chikmangalur	ABC Ltd.	Arabica	100 Year old Estate
Katlekhani Estate	513	Bababudan Giri, Chikmangalur	ABC Ltd.	Robusta/ Arabica	Single Origin Coffee & Dark Forest Coffee; Near Bhadra Wildlife Sanctuary
Kannagere Estate	48.56	Mudigere, Chikmangalur	ABC Ltd.	Arabica	-
Mac Estate	445.15	Sakleshpur	ABC Ltd.	Robusta/ Arabica	80 to 100 Years Old
Halasur Estate	137.59	Balehonnur, Chikmangalur	ABC Ltd.	Robusta	80 to 100 Years Old
Sri Nandi Estate	40.46	Cheekanhalli, Belur	Dr. Pradeep	Robusta/ Arabica	-
Joe's Sustainable Farm	46.54	Kirehully, Hassan	Dr. Anand Pereira	Robusta	Sustainable Coffee

Source: Modified from D.E. Allen et al., 2011

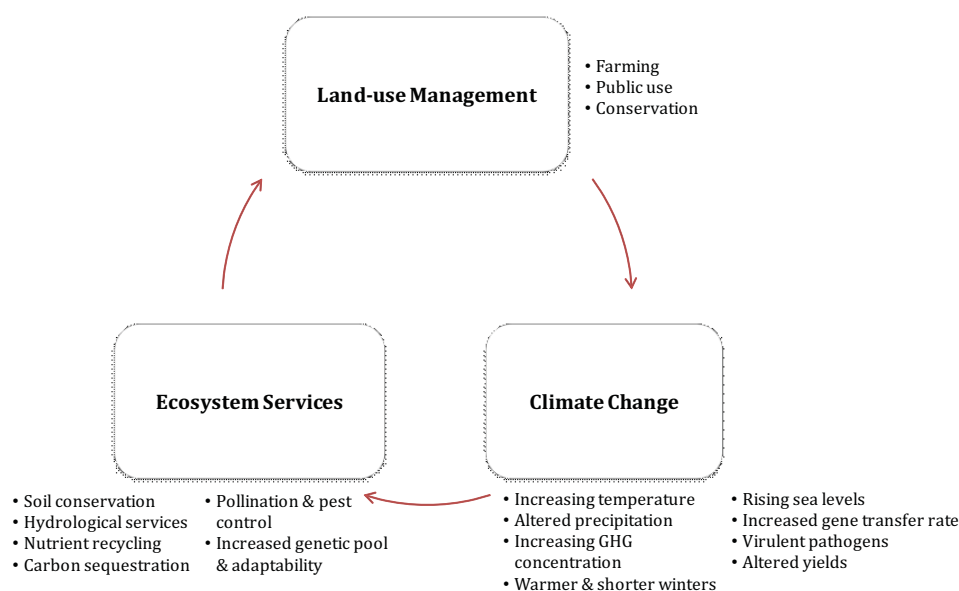
While an India wide study of coffee regions and their inter-linkages with BES would be ideal to determine the changing dynamics between the plantations and BES and the long-term outlook for coffee farmers, our intention of the authors is to provide a scoping study that demonstrates the trends to a global audience. Based on primary data available to us, we take a closer look at the relationship between coffee cultivation on these eight estates and its impact on the provisioning of ecosystem services via four main drivers, namely, soil conservation, hydrological services, nutrient recycling and carbon sequestration.

Main drivers of ecosystem services

The provisioning of ecosystem services is interactively linked with land-use management and climate change. Together, they form an intricate chain, wherein a change in either one has a cascading effect across all three (see Figure. 4.2). For example, elevated CO₂ concentration, increasing temperatures, atmospheric Nitrogen deposition and changes in total and seasonal distribution of rainfall and

extreme events such as droughts and floods will have an impact on soil biological processes, C and N cycling, and consequently on soil structure and erosion events, nutrient availability and plant diseases, and hence on ecosystem functionality and agricultural productivity (D.E. Allen et al., 2011).

Figure.4.2. Interactive linkage between land-use management, climate change and provisioning of ecosystem services



Source: Modified from D.E. Allen et al., 2011

Indicators are a composite set of measurable physical, chemical and biological attributes, which relate to functional processes and can be used to evaluate ecosystem services status, as affected by management and climate change drivers. Soil health indicators can be categorised into three categories; biological, chemical and physical (see Table.4.2.), which may be used as an indirect measure of soil function, serving to assess soil quality or health and its direction of change with time, by linking functional relationships among measurable attributes and monitoring for sustainable land management, including environmental impacts (Dalal et al. 2003; Doran 2002; Doran and Zeiss 2000).

Table.4.2. Soil health indicators and relations to processes and functions under projected climate change scenarios

Soil Health Indicators	Soil Processes Affected	Landscape scale (direct determination or estimated from pedotransfer functions)	Relevance to assess climate change impacts
Physical	Soil Structure	Aggregate stability, organic matter turnover	Aggregation, surface seal, indication of water and chemical retention and transportation
	Porosity	Air capacity, plant available water capacity, relative field capacity	Soil crusting, reduced seed germination, aeration, water entry
	Infiltration	Soil water availability and movement	Potential for leaching, productivity, erosion
	Bulk Density	Soil structural condition; compaction	Volumetric basis for soil reporting
	Soil Depth & Rooting	Plant available water capacity, subsoil salinity	Productivity potential; uncertain whether trends can be discerned over long time periods
	Soil/Plant Available Water & Distribution	Field capacity, permanent wilting point, macropore flow, texture	Water and chemical retention and transportation; yield
	Soil Protective Cover	Soil water and nutrient movement, soil stabilisation, C and N fixation	Soil physical movement, organic matter input and movement
Chemical	pH	Biological and chemical activity thresholds	Soil acidification, salinisation, electrical conductivity, soil structural stability
	EC	Plant and microbial activity thresholds	Soil structural decline; leachable salts
	Plant available N, P, K	Plant available nutrients and potential for loss	Capacity for crop growth and yield; environmental hazard (e.g. algal blooms)
Biological	Soil Organic Matter	Plant residue decomposition, organic matter storage and quality, macroaggregate formation	Loss of organic matter, soil aggregate formation, total organic C, soil respiration rate, nutrient supply
	• Light fraction or macro-organic matter	• Metabolic activity of soil organisms, net inorganic N flux from mineralisation and immobilisation	• Microbial activity, nutrient supply
	• Mineralisable C and N		
	Soil total C & N	C and N mass and balance	Soil structure, nutrient supply
	Soil Respiration	Microbial activity	Microbial activity
	Microbial Biomass C & N	Microbial activity	Soil structure, nutrient supply, pesticide degradation
	Microbial Quotients	Substrate use efficiency	Substrate quality
	Microbial Diversity	Nutrient cycling and availability	Biochemical activity, nutrient supply
Other Microbiological Indicators, Enzyme Activity	Other Microbiological Indicators, Enzyme Activity	Soil structure, labile carbon, K_m , V_{max} , K_i , Q_{10}	Biochemical activity, nutrient supply

Source: Modified from D.E. Allen et al., 2011

Table.4.3. Tree diversity in coffee agro forestry systems in Kodagu and in similar systems elsewhere in the world

Country	Region	Species Richness (%) ^a	Similarity (%) ^b	Reference
India	Kodagu	121	62	Bhagwat et al., 2005
Cameroon	South-western	35-36	5-13	Bobo et al., 2006
Ecuador	Western	53-81	21-47	Lozada et al., 2007
Mexico	Veracruz	97	87	Villavencio & Valdes, 2003

^a Values derived from published data reporting species richness in coffee agro forestry systems and in neighbouring forest reserves.

Values >100 suggest agro forestry systems with species richness higher than that of neighbourhood forests due to presence of non-forest species

^b Values derived from published data reporting species richness in coffee agro forestry systems and in neighbouring forest reserves. Differences in methods among studies mean the numerical comparisons shown here should be seen as only a rough guide

Source: Garica et al., 2009

Although land-use management practices in coffee agro forests in Karnataka have evolved over time, they still retain strong traditional roots. This has allowed coffee agro forests in the state to maintain a composition of species richness and native canopy cover, with a high degree of similarity to neighbourhood forest reserves. Tree diversity in coffee agro forest systems in Kodagu is the highest amongst similar systems elsewhere in the world (see Table.4.3); but recent global trends at the landscape level clearly point toward increased intensification of the cultivation system and a further loss of biodiversity, as in Central America (Somarriba et al., 2004; Vaast et al., 2005; Harvey et al., 2008). Therefore, it is essential for us to understand the drivers behind these trends in order to identify similar land-use management changes and determine their impacts on provisioning of ecosystem services in the Western Ghats region of Karnataka.

Analysis of Coffee Agroforestry Systems in Karnataka

For this study, the authors were able to extract primary soil health data of eight sample estates from soil testing reports of individual blocks and secondary data from available literature. Indicators are extrapolated from aforementioned primary and secondary sources and used in analysis of soil conservation on the sample estates, including average yield, average soil organic content, average pH, average electrical conductivity and average soil nutrients (NPK). Similarly, for water balance the authors have extrapolated average rainfall and average water recharge capacity; average carbon sequestration potential for climate change; whereas biodiversity and livelihood values are represented by possible economic benefits of pollinator activity and average labour employment per year and its contribution to income earning respectively.

Soil Organic Content (O.C.)

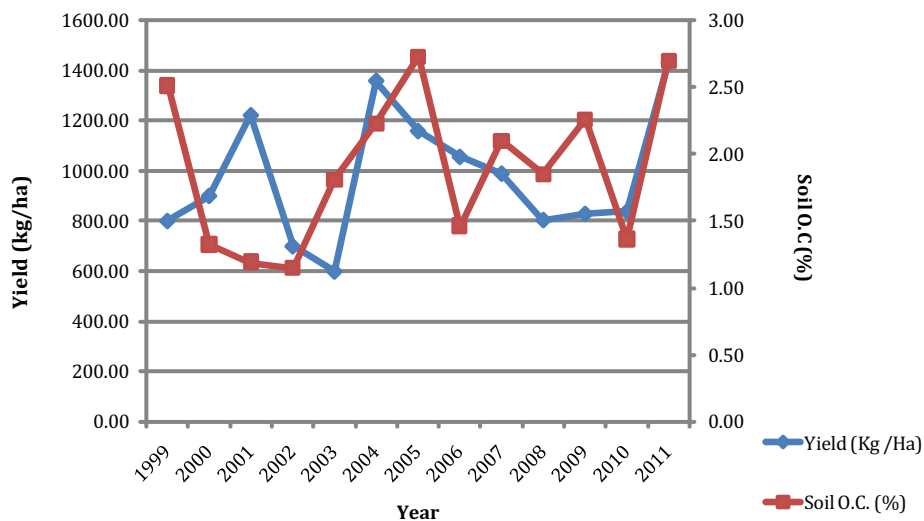
Soil OC is one of the most complex and heterogeneous components of soils and is considered an important attribute of soil quality (or soil health) due to the various functions it provides and/or supports. These functions include its contribution to the charge characteristics of soils; its role as sink for and source of carbon (C) and nitrogen (N); its regulation, albeit to a variable extent, of phosphorus and sulphur cycling; its ability to complex with multivalent ions and organic compounds;

the provision of microbial and faunal habitat and substrates; its affecting aggregate stability, trafficability, water retention and hydraulic properties (Haynes 2008; Weil and Magdoff, 2004). For this study, the authors have calculated the trend of soil OC on the eight sample estates alongside yield and rainfall.

Soil O.C. and yield

By plotting the trend of soil O.C. and the average yield data, for our eight sample estates from the years 1999 to 2011, we obtained mean values of 1.64 per cent for soil O.C. and 883.17 kg/ha for average yield. Corresponding standard deviations were 273.95 and 0.28 for average yield and soil O.C. respectively. Between 1999 and 2011, soil O.C. and average yield display polar trends. Soil O.C. declined from 2.51 per cent in 1999 to 1.15 per cent in 2002 (see Figure.4.3), while average yield increased from 800 kg/ha in 1999 to 1219.43 kg/ha in 2001. In 2003, average yield declined further to 600 kg/ha, whereas soil O.C. increased to 2.73 per cent in 2005. Post-2005 though, both soil O.C. and yield trends show a general decline, before simultaneously increasing to 2.7 per cent and 1428.72 kg/ha respectively, in 2011.

Figure.4.3. Yield-Soil O.C. trend for sample estates (1999 to 2011)



Source: Compiled by the authors

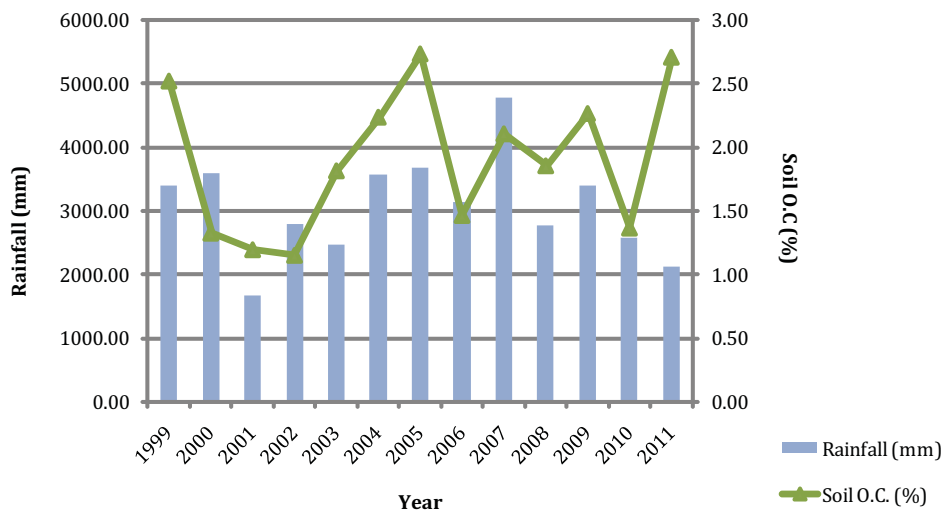
Soil OC has two main functions: a) it helps in the provisioning of ecosystem services and b) it helps in increasing productivity. Although the exact degree of the positive relationship between soil OC and yield was extremely difficult to predict for this study given lack of data. Nevertheless, literature available on the subject confirms that an increase in soil OC has in general a positive impact on agricultural production. Hence the increase in average yield in coffee observed in the sample estates can be attributed to the increasing trend in soil OC observed in most of the years, among other things. The factors believed to have caused a decline in soil OC in random years include less than average rainfall (see Figure.4.4) and increasing use of pesticides and herbicides as berry borer infestation spread across the traditional coffee growing states at an annual average spread of 6.5 per cent, from 2001 to 2009 (Coffee Board, 2012), among other things.

Soil O.C. and rainfall

Plotting the trends for average soil O.C and average rainfall (mean value of 3704.87 mm, with standard deviation of 44.29); we observe that a decline in soil O.C. corresponds with a decline in average rainfall over the years (see Figure.4.4). While average soil O.C declined from 2.51 per cent to 1.19 per cent between 1999 and 2001, average rainfall declined from 3395.47 mm to 1670.05 mm during the same period. The year 2005 and 2007 marked an increase in both, with average rainfall of 3666.15 mm and 4773.30 mm and soil O.C. of 2.23 per cent and 2.10 per cent respectively, before declining to 2563.96 mm and 1.36 per cent, in 2010. In contrast, 2011 has been marked by an increase in average soil O.C to 2.70 per cent while average rainfall declined to 2109.39 mm.



Figure.4.4. Rainfall-Soil O.C. trend for sample estates (1999 to 2011)



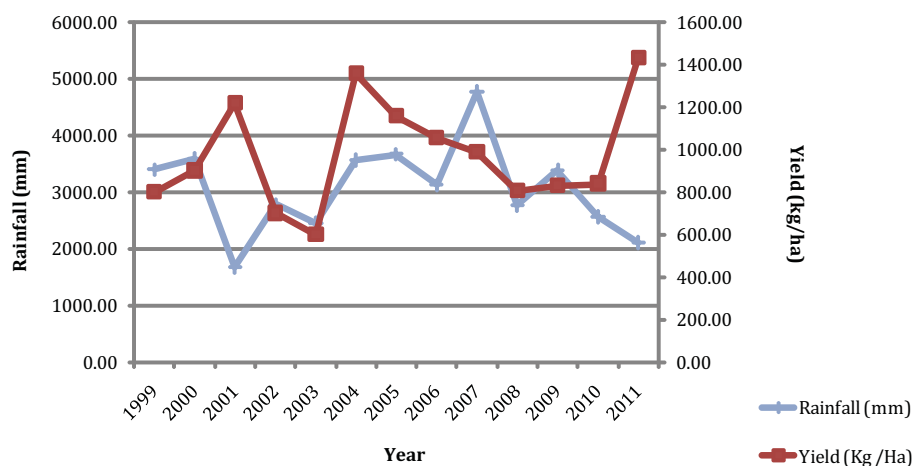
Source: Compiled by the authors

Rainfall has strong positive linkages with temperature, litter-fall and soil moisture; and is essential for composting of leaf litter. Commenting on the importance of organic matter input from tree pruning and litter-fall in maintaining or increasing soil, Dulormne et al. (2003) reported a 15% increase in soil carbon to a 20 cm depth after 10 years of silvopasture, with *Gliricidia sepium* in the French Antilles. Similarly, in Nigeria, Kang et al. (1999), found higher organic carbon concentrations (10.4 and 10.2 g kg⁻¹ for *Gliricidia* and *Leucaena*, respectively) associated with addition of pruning biomass as mulch (4.87 and 7.10 t ha⁻¹ yr⁻¹, respectively). According to the A. Youkhana and T. Idol (2009) study in Hawaii – which has similar sub-humid tropical climatic conditions as in the Western Ghats – mulch additions significantly increased soil carbon in the top 20 cm by 10.8 Mg ha⁻¹. Since rainfall is a dominant factor leading to litter-fall, temperature regulation and moisture availability; the occurrence of strong fluctuations in average annual rainfall trends with an apparent cycle of 12-14 years culminating in lower to very low levels of rainfall in the years 2014 to 2016 (CAFNET, 2011), would have a negative impact on soil OC in the absence of other factors.

Rainfall and yield

Climate variation in the form of erratic rainfall appears to be having an impact on coffee production in Karnataka (see Figure.4.5). Volatility in trend of average rainfall has increased in frequency, with 2001, 2003, 2008 and 2011 being low rainfall years; while 2000, 2004, 2007 and 2009 received very high rainfall. These fluctuations in rainfall coincide with fluctuations in coffee production to create extreme highs and lows in coffee production, with 2001 and 2004 producing around 1219.43 50-kg bags of coffee and 1356.18 50-kg bags of coffee respectively; while in 2002 and 2003 production almost halved to 700 50-kg bags of coffee and 600 50-kg bags of coffee respectively. Post-2003, trends in average yield and average rainfall have both declined. In 2011, average yield increased to 1428.72 50-kg bags of coffee despite a fall in average rainfall to 2109.39 mm, as a result of productivity gains due to better soil quality and availability of subsurface water for irrigation.

Figure.4.5. Rainfall-Yield trend for sample estates (1999 to 2011)



Source: Self generated

There is a strong positive linkage between rainfall and coffee yield, with drought years leading to a decline in production and years with above average rainfall increasing production; significant differences may occur due to the timing of rainfall. In 2009, heavy and unseasonal rainfall led to heavy losses in coffee production,

especially in Arabica production (Balaji, F., 2010). Similarly, in 2010, rainfall occurring after the blossoming stage for Arabica coffee plants delayed the harvest and lowered crop quality (U.S. Department of Agriculture, 2011). With the occurrence of extreme rainfall events on the rise in Western India (Goswami et al., 2006; Guhathakurta et al., 2010), the long-term trend of coffee production in Karnataka is likely to face greater uncertainties.

Nutrient balance (N, P, K)

Nutrient balance for nitrogen (N), phosphorous (P) and potassium (K) content was obtained from soil analysis data from across the sample estates on an annual basis. Based on data, we obtained mean values of 158.26 kg/ha, 42.79 kg/ha and 315.72 kg/ha, with corresponding standard deviations of 2.61, 2.18 and 5.09 for N, P and K respectively.

Box.4.1. Case Study – More trees less loss: Nitrogen leaching losses decrease with increasing biomass in coffee agroforests in Costa Rica (K.L. Tully et al., 2012).

Study conducted on eight coffee agroforests, in Costa Rica's Central Valley near Turrialba, based on monthly N and P concentrations measured in soil water using tension lysimeters (at 15 and 100 cm) between October 2008 and September 2009, and a water balance model – including effects of human interventions (fertilizer type and quantity), biology (shade trees), and chemistry (soil properties) on nutrient leaching losses – revealed that practices such as tree pruning and litter collection for mulch application enabled significant increases in soil C and N in the top 20 cm, of up to 10.8 and 2.12 Mg ha⁻¹ respectively.

Given the optimal ranges of soil N, P and K for coffee cultivation of 280-560 kg/ha, 9-22 kg/ha and 125-250 kg/ha respectively (Coffee Board, 2012); we can see that there is an imbalance in soil nutrient, with average N content being less and P and K being far greater than the recommended ranges. Nutrient cycling, especially N, is intimately linked with soil OC cycling (Weil and Magdoff 2004). Moreover, N losses decline with increasing shade tree biomass and density – as tree density increases; so does plant N demand – which provides a sink for added N (K.L. Tully et al., 2012). Systems with high species and functional diversity have an increased

capacity to retain nutrients due to greater number of opportunities to capture nutrients (Tilman et al., 1996). Also, the presence of trees helps reduce the vertical hydrological flux as the deep and extensive network of tree roots can utilize more water (Seyfried and Rao, 1991). Hence, composition of shade trees has direct relationship with soil nutrient balance and the declining trend of tree species diversity in coffee agroforests is likely to have some bearing on the nutrient imbalance observed in coffee estates in Karnataka.

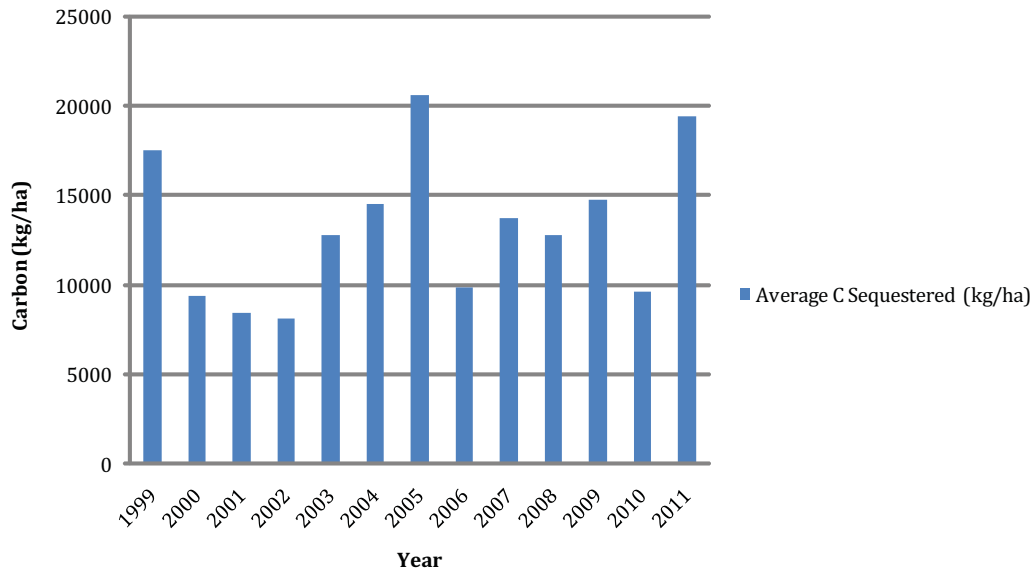
Carbon Sequestration

The world's soils contain a large stock of C, estimated at 2157–2293 Pg to a depth of 1m, comprising 1462–1545 Pg in organic forms and 695–748 Pg as carbonate (Batjes, 1996). Organic C in the surface 30 cm, which is most liable to change as a result of management or climate change, is estimated at 684–724 Pg: about twice the quantity of C currently in CO₂ in the atmosphere (D.S. Powlson et al., 2011).

Given the contribution of coffee agroforestry systems in sequestering carbon (ICO, 2012), to obtain the average C sequestered in sample estates, carbon sequestration values from the CAFNET study were used as a benchmark for carbon stored in tree, coffee, soil and litter. Given soil OC (%) and soil structure; the authors have extrapolated the average values of the carbon present in the tree, coffee, soil and litter in the sample estates by taking percentage ratios from CAFNET. The results (see Figure.4.6) show that average C sequestration capacity in the estates has varied from year to year, with a maximum average C sequestration of 20667.1 kg ha⁻¹ in the year 2005 and a minimum average C sequestration of 8126.68 kg ha⁻¹ in the year 2002.



Figure.4.6. Total C sequestered in sample estates (1999 to 2011)



Source: Self generated

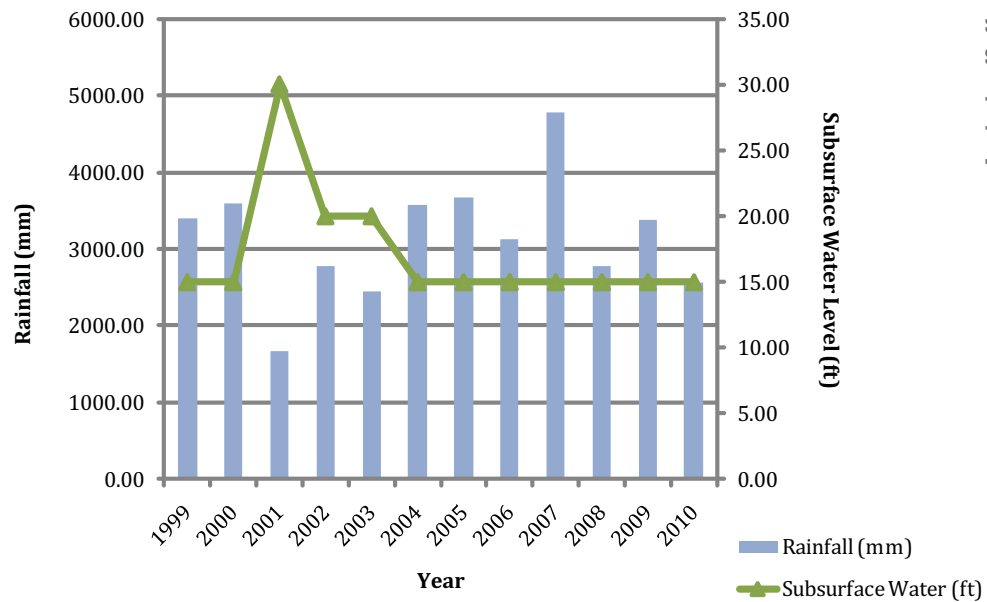
Coffee agroforestry systems can aid in increasing the C sequestration of agro ecosystems via plant biomass and soil organic matter (Albrecht and Kandji, 2003), since they have a higher input of organic material to the soil compared to single-crop systems and they also increase recycling of nutrients within the system (Oelbermann et al., 2006). Also, trees help stabilize soils against erosion and reduce soil disturbance through modified management practices (Ataroff and Monasterio, 1997). Furthermore, mulching has the capacity to reduce evaporation from the soil surface and thus to conserve soil water over a long period (Sands et al., 1999).

Water Balance

Estimates for water balance are extrapolated from the primary subsurface water data of the sample estates and secondary data, based on the assumption that the average values of subsurface water from one estate are an indicative value for the rest of the region. The results (see Figure.4.7) show that in 1999 rainfall and subsurface water levels were 3395.47 mm and 15 ft respectively. In the year 2001,

following a deficit, the rainfall declined to 1670.05 mm and simultaneously subsurface water level dropped to 30 ft. With a normalisation in rainfall from 2004 onwards, the subsurface water level has returned to 15 ft and remained constant over the years.

Figure.4.7. Subsurface water level & average rainfall in Sri Nandi Estate (1999 to 2010)



Source: Compiled by the authors

Rainfall has a direct impact on subsurface water since coffee growers in Karnataka are predominantly dependent on artificial water bodies like shallow tanks and wells for their irrigation needs, which also act as groundwater recharging bodies. Although, groundwater recharge depends on various factors other than rainfall, such as evapotranspiration, soil moisture characteristics, etc.; infiltration capacity has a positive correlation with soil porosity and organic matter present in coffee agroforestry systems. The authors estimate that overall coffee agroforestry systems in Karnataka have an average water recharging capacity of 8.582 million m³ and generate an economic value of INR 20.59 million (2008) (USD 0.37 million, the INR to USD conversion factor taken is 54.61, this being the six-month average until early October 2012).

Soil Erosion

Rainfall, temperature and wind are the main climatic factors influencing soil erosion. When the amount of rain water is in excess to the absorption capacity of the soil, movement of water on soil surface causes run-off. According to the Central Soil & Water Conservation Research Training Institute, Dehradun, approximately 16 tonnes/ha of top soil is eroded annually in India – four times the permissible limit of 4 tonnes/ha – affecting the nutrient balance, since eroded soil particle carry away with them attached nutrients to streams and rivers. Thick canopies, found in traditional polyculture agroforestry systems not only help in reducing soil run-off by breaking the through-fall of rain (i.e. percentage of rainwater that falls directly on the ground causing soil run-off), they also enable retention of soil moisture content by covering soil with a thick mulch layer of organic matter. Studies in Costa Rica show that runoff as a percentage of total rainfall was lower in agroforestry system (5.4 per cent) than monoculture (8.4 per cent) (P. Cannavo et al., 2011).

Coffee agroforests are characterised with good canopy, good undergrowth, leaf litter and interception help prevent soil erosion – thereby preventing loss of major nutrients like NPK and organic matter. The authors have used a replacement cost method; replacing nitrogen lost due to soil erosion by urea (46% N); phosphate by DAP; and potash by muriate of potash. According to estimates, coffee agroforests in Karnataka help prevent soil loss of up to 1818.6 million kg (i.e., 8602.81 kg/ha). The economic value of nutrient loss in soil erosion prevented by coffee agroforests is estimated at INR 177.53 million. (USD 3.25 million) (2008). This number is of some significance, given the increase in extreme rainfall events and decline in tree density in coffee agroforests across the region in recent years.

Summary

Climate change has a direct impact on coffee production and management practices of coffee agroforests in Karnataka. Intensification in monoculture practices is slowly transforming the traditional agroforestry landscape by reducing shade tree density and soil quality. Combined with continued increase in GHG emission via burning of fossil fuel and deforestation; temperatures in Karnataka and throughout India are projected to continue to rise during this century (Christensen et al., 2007). IPCC's mid-range scenario for future emissions of heat-trapping gases projects a warming of about 2.5°C in Karnataka by 2100; leading to a projected to increase in both annual rainfall totals and the number of extreme rainfall events along with climate warming (Rupa Kumar et al., 2006). This is likely to contribute to a 4–10 per cent decrease in overall crop production in South India by the end of the century, even under a low-emissions scenario (Lal, M., 2011).





Chapter 5: Coffee Cultivation in Karnataka – Implications for Livelihood and Biodiversity

The coffee agroforests of Karnataka comprise of a fragmented landscape, with a high density of remnant forest patches, protected areas and wildlife sanctuaries dispersed side by side.

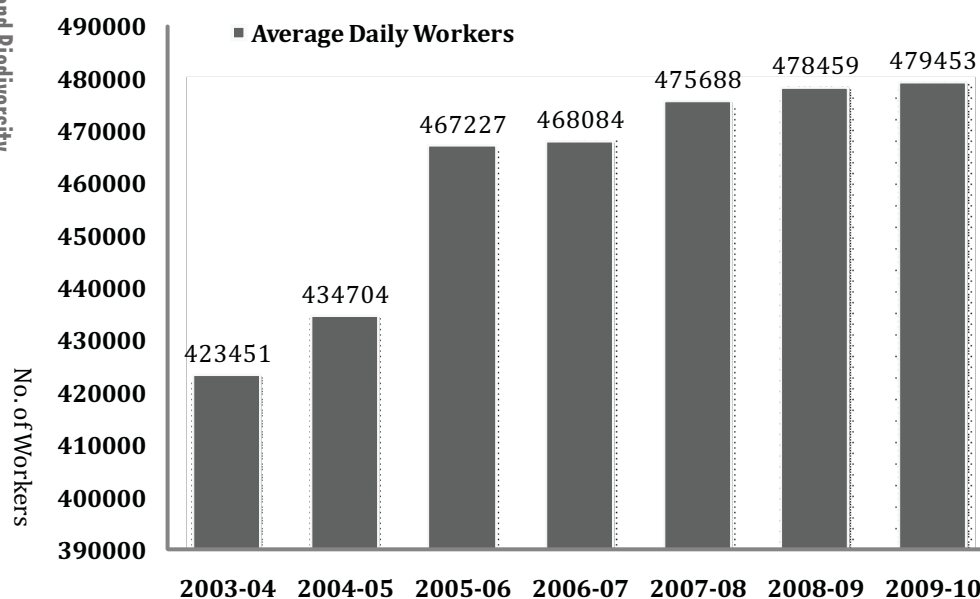
The coffee agroforests of Karnataka comprise of a fragmented landscape, with a high density of remnant forest patches, protected areas and wildlife sanctuaries dispersed side by side. This has led to the emergence of a unique mosaic for biodiversity in a region that is already known for the high richness and endemic nature of its flora and fauna. Several species, particularly elephants, although primarily located within the PA habitat, use the coffee agroforests as a secondary habitat for foraging and as corridors for movement across PAs – bringing them in direct conflict with coffee cultivators, but also increasing the opportunity for access to water, food and security that would not be present in non-coffee farms that tend to be more intensive in human presence, vehicle movement, etc.

Livelihoods in coffee agroforestry systems

Coffee agroforestry systems in Karnataka support a large population of mostly poor and indigenous tribal communities. An analysis of the coffee growers shows that out of the 67,181 coffee holdings in Karnataka in 2007-2008, 65,846 (or 98 per cent) holdings belonged to small farmers with less than 10 ha of land holdings (accounting for about 24.43 per cent of the total planted coffee area in the state) who depend largely on coffee for their income.

Historically, coffee plantations in Karnataka depend upon and provide livelihood to a large number of daily migrant workers, including women and indigenous tribal communities settled in the surrounding forest areas. As per data released by the Coffee Board of India, average daily number of workers employed on coffee estates has increased from 423,451 in 2003-2004 to 479,453 in 2009-2010 (see Figure.5.1).

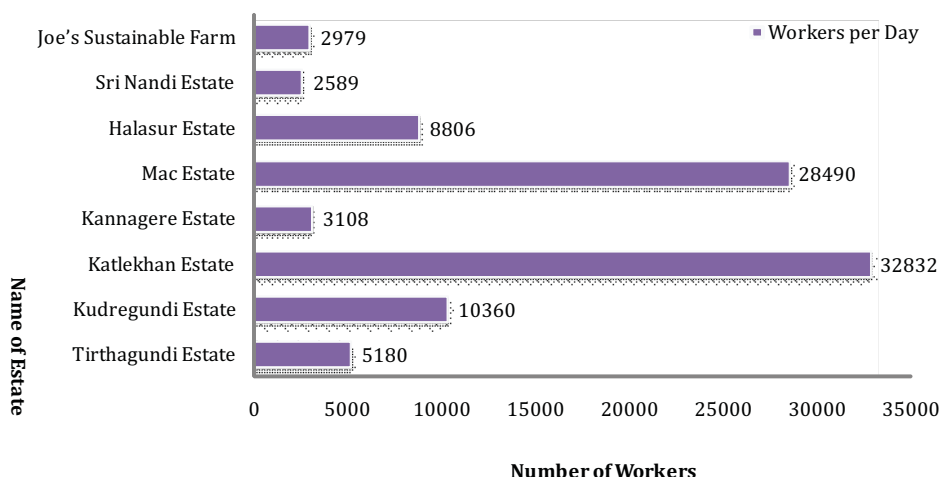
Figure.5.1. Average daily workers employed in Coffee Plantations in Karnataka



Source: Compiled from Coffee Database 2012, Coffee Board of India



Figure.5.2. Average number of workers employed in sample estates in 2012



Source: Compiled by the authors

Extrapolating data from the eight sample estates included in our study shows that 94,343 workers are employed daily in these estates (see Figure.5.2), at an average of 64 workers per ha. Apart from income received as daily wages, workers employed on the coffee estates also benefit from fuel-wood and other NTFP available in the coffee agroforests; giving them access to resources and alternative livelihood opportunities. Moreover, with over 60 per cent of the labour force constituted of women; coffee agroforests also play a pivotal role in gender empowerment. Loss in provisioning of ecosystem services essential for continuation of coffee cultivation are major a threat to these livelihoods, since they reduce profitability of cultivators by rendering existing producing areas unsuitable for coffee cultivation, and in extreme cases can result in shift in production to alternative crops requiring less labour.

Biodiversity in coffee agroforestry systems

There are several potential economic benefits accruing to coffee growers as a result of interaction with wildlife in the coffee agroforests. Given the lack of primary data of existing biodiversity within our sample estates, we take recourse in the existing literature on the subject to draw parallels based on a benefits transfer approach.

Tropical forests, such as the Western Ghats, are home to forest-dwelling bees and other pollinators who play a vital role in the pollination of Robusta (*C. canephora*) coffee, since Robusta being a self-incompatible species is dependent on pollinators for gene exchange between individuals (S. Krishnan et al., 2012). In Santa Fe, Costa Rica, bee-pollination boosted the yield by 20 per cent, reduced the incidence of pea-berries by 27 per cent and increased farm incomes by up to 7 per cent; bringing in an extra US\$60,000 annually for the coffee plantation (Ricketts T. H et al., 2004). Also, the coffee plantations of Chikmagalur harbour a rich assemblage of mammals, birds and butterflies including a number of rare and endangered species unique to the Western Ghats; indicating that coffee plantations have the potential to play a major part in wildlife conservation in the region (A. Bali et al., 2007).

Traditional notions of a trade off between biodiversity and profitability in coffee cultivation are a misnomer. Studies in Mexico demonstrate that high-biodiversity coffee cultivation can be compatible with high profitability, and has significant potential for conserving biodiversity in coffee-growing regions, but only as a substitute for low biodiversity coffee cultivation, not forest (C. Gordon et al., 2007). Moreover, biodiversity contributes to productivity, resilience in farming systems, income generation, nutritional values, and food and livelihood security for numerous societies; apart from providing ecosystem services on farms, such as pollination, fertility and nutrient enhancement, insect and disease management, and water retention. More bio diverse, lower input systems, particularly those with non-coffee revenue generators, incur less economic risk, cushioning coffee growers against coffee price dips. This economic advantage provides an additional important conservation advantage.

Cost of coffee cultivation

The establishment costs of coffee cultivation are quite substantial and include cost of renovation pits, contour drains, planting and cost of seedlings. In addition, there are fixed costs by way of irrigation investments and fencing costs. Recurring costs include material costs such as fertilizers, manure and pesticides and labour costs for applying fertilizers, manure and pesticides, repairs and maintenance, supervision, berry picking, etc.

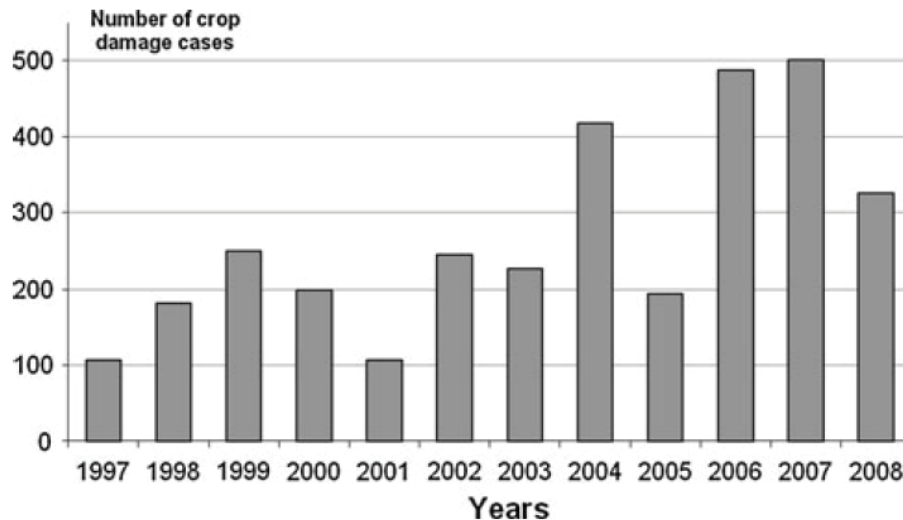
In 2011, the daily wages of coffee workers in Karnataka was approximately INR 247 per day, including wages and benefits (based on personal communication to authors). This corresponds to an average cost of INR 15,808 per ha per day as labour costs on our sample estates. Similarly, average daily capital expenditure of INR 9,515 per ha per day is obtained by summing the average expenditure incurred on diesel (required for tractors, irrigation and processing) of INR 6,426 per ha per day and the average cost of maintenance of equipment and machinery of INR 3,089 per ha per day. Hence average total cost of coffee cultivation (capital cost + labour cost) for our sample estates was INR 25,323 per ha per day, in 2011. Wage rates of coffee workers have risen steadily over the years, increasing from INR 27 per day in 1994 to INR 140 per day in 2012 (Coffee Board, 2012). These numbers are important as they demonstrate the extent of earnings of the local communities and the livelihoods that would need to be compensated if climate change affects the production capacity of the estates.

External costs of coffee cultivation and human-wildlife conflict

Apart from the above mentioned costs, there are also significant external costs incurred by coffee cultivators by way of wildlife damage costs and defensive costs incurred in order to protect against wildlife damage. Recurrence of such costs, along with intensification of agricultural practices, plays a significant role in the increasing trend of human-wildlife conflict – the best example being human-elephant conflict (HEC) in Karnataka (see Figure.5.3).



Figure.5.3. Temporal trend in annual number of crop damage incidents in Virajpet Division from 1997 to 2008



Source: P. Bal et al, (2011)

Elephants cause 3–10 human casualties a year and cost the community INR 882,000 in crop-raiding compensations per year (Kulkarni et al. 2007; Bal et al. 2008). The main reasons behind the cause of HEC in Karnataka are the high elephant density and major landscape changes due to degradation of natural habitats. Although the intensity of HEC has increased over time and is exhibiting new seasonal patterns (P. Bal, et al., 2011); based on the CAFNET study, for a significant percentage of coffee growers (16 percent) HEC problem was only 5 years old – indicating that newer areas are becoming part of the conflict zone.

The increasing trend of elephant movement outside the forest and into nearby coffee estates are a result of the decrease in the capacity of the forests to sustain a growing elephant population due to degradation of original habitats, the presence of artificial water bodies round the year, availability of better vegetation, including preferred fruit trees on the estates and the evolving patterns of elephant behaviour. This is evident in the fact that the regions of highest conflict are those sharing boundaries with natural forests (CAFNET, 2011). In 1999-2000, the total external costs for wildlife damage and defence were INR 803.1 per ha for coffee holdings less than 2.5 ha in size, and INR 495 per ha for coffee holdings of 10 ha and above sizes, in the Western Ghats region (K.N. Ninan, J. Sathyapalan, 2005).

Despite the growing trends of HEC and crop damage, there remains a wide consensus among coffee growers on the importance of wildlife, especially for key species such as elephants, in terms of their cultural, aesthetic and generational values. According to an estimate, they are willing to spend 35.8 human days per household for participatory elephant conservation amounting to over INR 6003 per household per annum in terms of foregone income (*ibid*); bearing testimony to the positive attitude that local communities have towards biodiversity conservation in general and for wildlife protection in particular.

Summary

In summary, biodiversity has been and continues to be an important part of coffee agroforestry systems. It has the potential to provide multiple products and services, facilitate organic production, and support the development of livelihoods and eco-tourism enterprises. Maintaining and integrating trees and wildlife on coffee farms is recommended to maintain and enhance the sustainability of coffee production and the flow of benefits to the surrounding environment and society at large.



Conclusion

It is evident that coffee estates have a clear link with aiding the preservation and maintenance of ecosystem services such as soil OC, soil erosion and water recharge. It is also apparent that rainfall patterns have an impact on coffee productivity and that the estates of Southern Karnataka are then vulnerable to rainfall variability with serious implications for livelihoods as climate change creates erratic weather occurrences. While, the study is an indication of the trends of the dynamics between the coffee estates and the ecosystem they inhabit, it is also a preliminary analysis laying down the framework for a much needed in-depth assessment of the suite of ecosystem services and biodiversity in coffee estates. The economic value that coffee provides to the districts of Chigmangalur, Hassan and Kodagu is evident based on the employment potential. It is also unmistakable that the revenue generated by these coffee growing districts is a significant portion of each district's GDP. Unrecognised and overlooked in 'business as usual' scenarios this can lead to monetary loss for the economy of Karnataka and therefore, requires a more rigorous evaluation that can lead to more informed decisions about how to enhance the positive correlation between coffee and BES.

This assessment would further be an opportunity for more guided global investments in conservation that can result in multiple benefits, where the acknowledgment of the inter-linkages between BES and coffee farming provides economic incentives for estate owners to have widespread adoption of sustainable practices. It can also simultaneously deliver benefits for local communities and wildlife, leading to a win-win scenario that is based upon the real challenges faced on the ground.



REFERENCES

Allen, D.E., Singh, B.P., and Dalal, R.C., (2011), *Soil Health Indicators Under Climate Change: A Review of Current Knowledge*. Springer-Verlag Berlin Heidelberg 2011, DOI 10.1007/978-3-642-20256-8_2

Somarriba, E., C. Harvey, M. Samper, F. Anthony, J. Gonzalez, C. Staver, and R. A. Rice., (2004), Biodiversity conservation in neotropical coffee (*Coffea arabica*) plantations. Pages 198–226 in G.

Schroth, G. A. B. da Fonseca, C. Harvey, C. Gascon, H. L. Vasconcelos, and A.-M. N. Izac, editors. *Agroforestry and biodiversity conservation in tropical landscapes*. Island Press, Washington, D.C.

Vaast, P., J. Beer, C. Harvey, and J. Harmand, (2005), Environmental services of coffee agroforestry systems in Central America: a promising potential to improve the livelihoods of coffee farmers' communities. Pages 35–39 in CATIE, editor. *Integrated management of environmental services in human-dominated tropical landscapes*. Tropical Agriculture Research and Higher Education Center, Turrialba, Costa Rica.

Harvey, C. A., et al., (2008), Integrating agricultural landscapes with biodiversity conservation in the mesoamerican hotspot. *Conservation Biology* 22:8–15

Garica et al., (2009), Biodiversity Conservation in Agricultural Landscapes: Challenges and Opportunities of Coffee Agroforests in the Western Ghats, India. *Conservation Biology*, Vol. 24, No. 2, 479–488.

Dalal R.C., Eberhard R., Grantham T., Mayer D.G., (2003), application of sustainability indicators, soil organic matter and electrical conductivity, to resource management in the northern grains region. *Aust J Exp Agric* 43:253–259Doran 2002;

Doran J.W., Zeiss M.R., (2000), Soil health and sustainability: managing the biotic component of soil quality. *Appl Soil Ecol* 15:3–11

Batjes, N.H., 1996. Total carbon and nitrogen in the soils of the world. *European Journal of Soil Science* 47, 151–163.

CAFNET, (2011), *CAFNET Final Report (January 2007 to September 2011)*, CAFNET India (UASB, CBI and FIP)

Powlson, D.S., et al., (2011), Soil management in relation to sustainable agriculture and ecosystem services. *Food Policy* 36 (2011), 572–587

Tully, K.L., Lawrence, D., Scanlon, T.M., (2012), More trees less loss: Nitrogen leaching losses decrease with increasing biomass in coffee agroforests. *Agriculture, Ecosystems and Environment* 161 (2012), 137–144

Albrecht, A., Kandji, S.T., (2003). Carbon sequestration in tropical agroforestry systems. *Agriculture, Ecosystems & Environment* 99, 15–27.

Oelbermann, M., Voroney, R.P., Kass, D.C.L., Schlonvoigt, A.M., (2006), Soil carbon and nitrogen dynamics using stable isotopes in 19- and 10-year-old tropical agroforestry systems. *Geoderma* 130 (3–4), 356–367

Ataroff, M., Monasterio, M., (1997), Soil erosion under different management of coffee plantations in the Venezuelan Andes. *Soil Technology* 11, 95–108.

Sands, P.J., Rawlins, W., Battaglia, M., (1999), Use of a simple plantation productivity model to study the profitability of irrigated (*Eucalyptus globulus*). *Ecological Modelling* 117, 125–141.

Balaji, F., (2010), Decline in Indian coffee productivity levels alarming: Upasi. *Headlines India*, September 14.

U R L : <http://headlinesindia.mapsofindia.com/business-news/coffee/decline-in-indian-coffee-productivity-levels-alarming-upasi-63203.html>.

U.S. Department of Agriculture, (2011), India coffee annual. GAIN report no. IN1147. Washington, DC.

Goswami, B.N., V. Venugopal, D. Sengupta, M.S. Madhusoodanan, and P.X. Xavier, (2006), Increasing trend of extreme rain events over India in a warming environment. *Science* 314:1442–1445

Guhathakurta, P., P. Menon, A.B. Mazumdar, and O.P. Sreejith, (2010), Changes in extreme rainfall events and flood risk in India during the last century. Research report no. 3/2010. Pune, India: National Climate Center, India Meteorological Department

Lal, M., (2011), Implications of climate change in sustained agricultural productivity in South Asia. *Regional Environmental Change* 11(Suppl.1):S79–S94

Christensen, J.H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R.K. Kolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr and P. Whetton, (2007), Regional climate projections. In: *Climate change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller. Cambridge, UK, and New York, NY, USA: Cambridge University Press

Rupa Kumar, K., A.K. Sahai, K. Krishna Kumar, S.K. Patwardhan, P.K. Mishra, J.V. Revadekar, K. Kamala, and G.B. Pant, (2006), High-resolution climate change scenarios for India for the 21st century. *Current Science* 90(3):334–345

Weil RR, Magdoff F., (2004), Significance of soil organic matter to soil quality and health. In: Weil RR, Magdoff F (eds) *Soil organic matter in sustainable agriculture*. CRC press, Florida, pp 1–43

P. Bal, C.D. Nath, K. M. Nanaya, C., G. Kushalappa, C. Garica, (2011), Elephants Also Like Coffee: Trends and Drivers of Human-Elephant Conflicts in Coffee Agroforestry Landscapes of Kodogu, Western Ghats, India. *Environmental Management* (2011) 48:263–275

Seyfried, M.S., Rao, P.S.C., 1991. Nutrient leaching from two contrasting cropping systems in the humid tropics. *Trop. Agric.* 68, 9–18.

P. Cannavoa, J. Sansouletb, J.M. Harmanda, P. Siles, E. Dreyerd, P. Vaast, (2011), Agroforestry associating coffee and *Inga densiflora* results in complementarity for water uptake and decreases deep drainage in Costa Rica. *Agriculture, Ecosystems and Environment* 140 (2011) 1–13

Ricketts T. H., Daily G. C. , Ehrlich P.R. & Michener C. D., (2004), *PNAS Online Early Edition* (2004)

Archana Bali, Jignasu Dolia, M.O. Anand, (2007), An assessment of biodiversity in coffee plantations: A report on a tri-taxa study in coffee plantations in Chikmagalur. Center for Wildlife Studies, Bangalore

Bhagwat, S.A., Kushalappa, C.G., Williams, P.H. and Brown, N.D. (2005) 'Landscape Approach to Biodiversity Conservation of Sacred Groves in the Western Ghats of India', *Conservation Biology* 19 (6): 1853-1862

Lange, B., Slade, B., Kwok, I., (2009), Strategic Report for Peet's Coffee and Tea, Oasis Consulting. URL: <http://economics-files.pomona.edu/jlikens/SeniorSeminars/oasis/reports/PEET.pdf>

Taylor, (1965), *N. Plant Drugs that Changed the World*. New York, NY: Dodd, Mead
Monaco, L. C., (1977), CONSEQUENCES OF THE INTRODUCTION OF COFFEE RUST INTO BRAZIL. *Annals of the New York Academy of Sciences*, 287: 57–71. doi: 10.1111/j.1749-6632.1977.tb34231.x

Neilson, J., (2008), Environmental Governance in the Coffee Forests of Kodagu, South India. *Transforming Cultures eJournal*, North America, 3, Feb. 2008.
URL: <http://epress.lib.uts.edu.au/journals/index.php/TfC/article/view/680/611>

Kariappa, C.P., Dhunjeebhoy, H.D., Ramaswamy, V., and Datta, A. (2004), *Planting Times*, MacMillan and UPASI, Bangalore

Richter, G. (1870), *Gazetteer of Coorg: Natural Features of the Country and the Social and Political Condition of its Inhabitants*. Reprinted 2002, New Delhi: Low price Publications

Specialty Coffee Association of America, (2012), *Coffee Facts and Statistics*
URL: <http://www.scaaevent.org/PDF/Press%20Kit/2012/Facts%20and%20Figures.pdf>

Coffee Board, (2010), *70th Annual Report: 2009-10 A Perspective View*, Coffee Board of India. URL: <http://www.indiacoffee.org/userfiles/70th%20Annual%20Report.pdf>

Coffee Board, (2012), *Database on Coffee: June 2012, Market Intelligence & Statistical Unit* Coffee Board. URL: www.indiacoffee.org

Morris D.W. (1995) Earth's peeling veneer of life. *Nature*, 373, 25.

Garcia, C., Marie-Vivien, D., Kushalappa, C. G., Chengappa, P. G., and Nanaya, K.M. (2007) 'Geographical Indications and Biodiversity in the Western Ghats: Can labelling benefit producers and the environment in a mountain agroforestry landscape?' *Mountain Research and Development*, 27 (3), pp206-210

Ukers, W. H. (1935) *All About Coffee*. New York: The Tea and Coffee Trade Journal Company

Ninan, K.N., Jyothis, S., Babu, P., Ramakrishnappa, V., (2001), Economic Analysis of Biodiversity Conservation: the Case of Tropical Forests in the Western Ghats, India. ISEC, Bangalore

Caleb Gordon, Robert Manson, Jeffrey Sundberg, Andrea Cruz-Ango', (2007), Biodiversity, profitability, and vegetation structure in a Mexican coffee agroecosystem. Agriculture, Ecosystems and Environment 118 (2007) 256–266

Coffee Board, (2012), Database on Coffee: June 2012, Market Intelligence & Statistical Unit Coffee Board. URL: www.indiacoffee.org

CII, (2012), Investment Climate: A Report on Southern States of India, CII-SR Economic Affairs and Governance Forum

Government of Karnataka, (2006), Karnataka Agricultural Policy 2006, Department of Agriculture, Government of Karnataka
URL: <http://raitamitra.kar.nic.in/Agri%20Policy%20Eng.pdf>

Government of Karnataka, (2011), Economic Survey of Karnataka 2010-2011, Directorate of Economics and Statistics, Government of Karnataka
URL: http://planning.kar.nic.in/sites/planning.kar.nic.in/files/Economic_Survey/8State%20Income%20&%20Prices.pdf

Rao, Vidya S., (2012), Impact of Grevillea Robusta Composition on Bird Diversity in Coffee Plantations in Cauvery Watershed Area of Coorg District

Venkatachalam, Lakshmi (2005): Perspectives on sustainability and globalization and the challenges for the coffee sector, Ms. Lakshmi Venkatachalam, Former Chairperson, Coffee Board of India, presentation at the 2nd World Coffee Conference, Salvador, Bahia, Brazil - 23-25 September 2005

International Coffee Organisation, (2002), The Global Coffee Crisis: A Threat to Sustainable Development, URL: www.ico.org

Upendranath, C., (2010), Coffee Conundrum: Wither the Future of Small Growers in India?

Pradeepkumar, T., Suma, B., Jyothibhaskar and Satheesan, K.N., (2008), Management of Horticultural Crops: Vol 11 Horticulture Science Series: In 2 Parts, New India Publishing Agency

Hagger, Jeremy, (2008), Impact of Climate Change on Coffee Farming Households in Central America and Steps for Adaptation in the Future, Centre for Tropical Agricultural Research and Training (CATIE)
URL: http://web.catie.ac.cr/congreso/jeremy/Paper_climate.pdf

Government of Karnataka, (2004), State of environment report and action plan 2003, Department of Forest, Ecology and Environment, Bangalore

Pierce, D. and Moran, D., (1994), The economic value of biodiversity, Earthscan, London

Shyamsundar, P. and Kramer, R.A., (1996), Tropical Forest Protection – an empirical analysis of the costs borne by local people, Journal of Environmental Economics and Management, 31 (2) (1996) (U.S.A.)

- Shyamsundar, P. and Kramer, R.A., (1997), Biodiversity conservation—at what cost? A study of households in the vicinity of Madagascar's Mantadia National Park, *Ambio*, 26 (3) (1997), pp. 180–184 (May)
- Borkhataria, R.R., Collazo, J.A. & Groom, M.J. (2006) Additive effects of vertebrate predators on insects in a Puerto Rican coffee plantation. *Ecological Applications*, 16, 696–703.
- Philpott, S.M., Perfecto, I. & Vandermeer, J., (2008), Effects of predatory ants on lower trophic levels across a gradient of coffee management complexity. *Journal of Animal Ecology* 77: 505-511.
- Klein, A.-M., Cunningham, S. A. Bos, Merijn, Steffan-Dewenter, I., (2008), Advances in pollination ecology from tropical plantation crops. *Ecology* 89: 935-943
- Ricketts, T. H., (2004), Tropical forest fragments enhance pollinator activity in nearby coffee crops. *Conservation Biology* 18:1262–1271.
- Steffan-Dewenter, I., et al., (2007), Tradeoffs between income, biodiversity, and ecosystem functioning during tropical rainforest conversion and agroforestry intensification. *Proceedings of the National Academy of Sciences of the United States of America* 104:4973-4978
- Krishnaswamy, J., Bawa, K. S., Ganeshaiah, K. N., & Kiran, M. C., (2009), Quantifying and mapping biodiversity and ecosystem services: Utility of a multi-season NDVI based Mahalanobis distance surrogate. *Remote Sensing of Environment*, 113, 857–867
- Kumar, B.M and P. K. R. Nair, (2006), Carbon sequestration potential of tropical homegardens in Tropical Homegardens: A Time-Tested Example of Sustainable Agroforestry., Springer Netherlands, 2006. Pages: 185-204.
- Olchev, A., et al., (2008), Effects of land-use changes on evapotranspiration of tropical rain forest margin area in Central Sulawesi (Indonesia): Modelling study with a regional SVAT model. *Ecological Modelling* Volume 212, Issues 1-2, 24. Pages 131-137
- International Trade Centre, (2010), Climate Change and the Coffee Industry, Geneva, ITC, 2010, vi, 28 pages (Technical Paper)
URL:http://www.intracen.org/uploadedFiles/intracenorg/Content/Exporters/Sectoral_Information/Agricultural_Products/Organic_Products/Climate-Coffee-Ch-13-MS-ID-3-2-2010ff_1.pdf
- Pinto H.S. Assad E.D. Zullo J, Brunini O. (2007), *Acqueamiento Global e a Agricultura*
- Critical Ecosystem Partnership Fund, (2007), Ecosystem Profile: Western Ghats and Sri Lanka Biodiversity Hotspot, Western Ghats Region. Ashoka Trust for Research in Ecology and Environment, Bangalore
- Daniels, R.J.R., Gadgil, M., Joshi, N.V., (1995), Impact of human extraction on tropical humid forests in the Western Ghats Uttara Kannada, South India. *Journal of Applied Ecology* 32, 866-874
- Karnath, K.K., Curran, L.M., Reuning-Scherer, (2006), Village size and forest disturbance in Bhadra Wildlife Sanctuary, Western Ghats, India. *Biological Conservation* 128, 147-157

Menon, S., Bawa, K.S., (1997), Applications of geographic information systems, remote sensing and a landscape ecology approach to biodiversity conservation in the Western Ghats. *Current Science* 73, 134-145

Jha, C.S., Dutt, C.B.S, Bawa, K.S., (2000), Deforestation and land use changes in Western Ghats, India. *Current Science* 79, 231-238

Damodaran, A., (2002), Conflict of trade-facilitating environmental regulations with biodiversity concerns: the case of coffee-farming units in India. *World Development* 30, 1123-1135

Pascal, J.P., (1988). Wet evergreen forests of the Western Ghats of India: ecology, structure, floristic composition and succession. Institut Français de Pondichéry, Pondicherry.

Vasudevan, K., Kumar, A., Chellam, R., (2006), Species turnover: the case of stream amphibians of rainforests in the Western Ghats, southern India. *Biodiversity and Conservation* 15, 3515–3525

Biju, S.D., Bossuyt, F., (2006), Two new species of *Philautus* (Anura, Ranidae, Rhacophorinae) from the Western Ghats, India. *Amphibia-Reptilia* 27, 1–9.

Parmesan, C., Yohe, G., (2003), A globally coherent footprint of climate change impacts across natural ecosystems. *Nature* 421, 37–42.

Donald, P.F., Evans, A.D., (2006), Habitat connectivity and matrix restoration: the wider implications of agri-environment schemes. *Journal of Applied Ecology* 43, 209–218.





With most of India's unique shade-grown coffee produced in the threatened biodiversity hotspot of the Western Ghats, there is a clear ecology-economy-equity link. What role can coffee play in addressing climate change and protecting ecosystems and livelihoods in India? Does the industry have a future? These are some of the questions examined in this study.

The study, *Coffee to go ? The vital role of Indian coffee to ecosystems and livelihoods*, highlights the interlinkages between shade-grown coffee practices in representative areas of Karnataka and their contribution to maintaining and enhancing ecosystem services and local socio-economic development.

Experts, donors, practitioners, policy makers and all coffee drinkers are encouraged to read this report

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This study has been supported by Cafe Coffee Day
The printing of this report has been supported by
Coffee Board of India

