# Integrating Mitigation and Adaptation to Climate Change in Orissa, India

## Coupling Entrepreneurial Agricultural Mechanization with Village-Based Biodiesel Production

by

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## Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

## Abstract

India's strong agrarian economy, global location and climatic zoning make it highly vulnerable to the potential effects of climate change. Recent evidence of shortening cropping seasons has raised interest among academics and policy makers in tools for adaptation. Timely sowing and appropriate mechanization have been identified as attractive adaptation tools. Mechanization using locally produced biodiesel in place of conventional fossil fuel provides a relatively low-cost and sustainable opportunity to mitigate carbon emissions. An enterprise model in which farmers invest in machinery for custom hire coupled with community-produced biodiesel offers one approach to integrated adaptation and mitigation mechanisms for climate change.

This research analyses agricultural practices and small farm mechanization in the state of Orissa, India, drawing on a village case study. Primary data is from twelve key informant interviews with farmers, academics and NGO representatives in India. Secondary data analysis includes Indian and Orissan government documents and reports from international organizations regarding agricultural mechanization, sustainability, resiliency and climate change.

The results of this study indicate that joint mitigation and adaptation mechanisms implemented at the community level can address impacts of climate change while also offering opportunities for livelihood benefits, poverty alleviation and income generation. This research contributes to growing literature on adaptation and mitigation tools for climate change and adds an integral focus on small-scale opportunities within the broader scope of sustainable agriculture and biofuel development in India.

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# List of Abbreviations

| | |
|---|---|
| APICOL | Agricultural Promotions and Investment Corporation of Orissa, Ltd. |
| AR4 | Fourth Assessment Report of the Intergovernmental Panel on Climate Change |
| BBC | British Broadcasting Corporation |
| BBS | Bhubaneshwar, Orissa |
| COP15 | 15th Conference of Parties under Kyoto Protocol in Copenhagen, Dec 2009 |
| CRED | Centre for Research on the Epidemiology of Disasters |
| CSO | Central Statistical Organization |
| CTx GreEn | Community-based Technologies Exchange fostering Green Energy partnerships |
| DAFP | Department of Agriculture and Food Production (Orissa) |
| DAg | Agricultural Department (Orissa) |
| DEn | Energy Department (Orissa) |
| DES | Directorate of Economics and Statistics (Orissa) |
| DoAC | Department of Agriculture & Cooperation (India) |
| DPI-NGO | United Nations Department of Public Information |
| FAO | Food and Agriculture Organization |
| GHGs | Greenhouse Gases |
| GoI | Government of India |
| GoO | Government of Orissa |
| GV | Gram Vikas |
| ICO | International Coffee Organization |
| IDD | International Disaster Database |
| IDST | Government of India Department of Science and Technology |
| IIT | Indian Institute of Technology |
| IMD | International Meteorological Department |
| IPCC | Intergovernmental Panel on Climate Change |
| IRRI | International Rice Research Institute |
| ISO | International Standardization Organization |
| MANTRA | Movement and Action Network for Transformation of Rural Areas |
| MoA | Ministry of Agriculture (India) |
| MoEA | Ministry of External Affairs (India) |
| MoHA | Ministry of Home Affairs (India) |
| MNRE | Ministry of New and Renewable Energy (India) |
| MPNG | Ministry of Petroleum & Natural Gas (India) |
| MSPI | Ministry of Statistics and Programme Implementation (India) |
| NAPCC | National Action Plan on Climate Change (India) |
| OECD | Organization for Economic Co-operation and Development |
| OFDC | Orissa Forest Development Corporation |
| OUAT | Orissa University of Agriculture and Technology |
| PC | Planning Commission (India) |
| PMCCC | Prime Minister's Council on Climate Change |
| RCDC | Regional Centre for Development Cooperation |
| RHDP | Rural Health and Development Program (Gram Vikas) |
| TAR | Third Assessment Report of the Intergovernmental Panel on Climate Change |
| UNDP | United Nations Development Programme |
| UNEP | United Nations Environment Programme |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| UNFCCC | United Nations Framework Convention on Climate Change |
| UW | University of Waterloo |
| VCS | Voluntary Carbon Standard |
| VLB | Village Level Biodiesel |
| WB | The World Bank |
| WMO | World Meteorological Organization |

# 1. Introduction

## 1.1. Statement of Purpose

The purpose of this study was to assess one set of integrated mitigation and adaptation mechanisms for responding to impacts of climate change in Orissa, India. The hypothesis of the research is that use of mechanized agricultural tools fuelled with locally produced and sustainable biofuel offers opportunities to increase community resilience, bolster livelihoods and local economic development and improve agricultural productivity in the face of changing regional climate patterns.

## 1.2. Research Question

The research question for this study is: How can mitigation and adaptation mechanisms for climate change be integrated in the context of rural agricultural communities in Orissa, India. What are the opportunities and challenges?

## 1.3. Objective

The objective of this study is to use one detailed village level case study to explore the potential to integrate mitigation and adaptation strategies for climate change in Orissa, India. The mechanisms explored include entrepreneurial agricultural mechanization (machinery for custom hire as a business) and local sustainable biofuel production.

## 1.4. Rationale

Orissa is a densely populated coastal area that has been deemed highly vulnerable to climate change by the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) (Parry, Canziani, Palutikof, van der Linden & Hanson, 2007). Among Orissa's climate-related concerns are increased incidence of extreme weather conditions such as flood, drought, hurricanes and cyclones; coastal erosion; shortened cropping seasons; erratic monsoon; increased incidence of rain outside monsoon; increased intensity of non-monsoon rain; and, higher mean average surface temperatures and sea surface temperatures (Jaswal, 2010; Kalra et al., 2008; The World Bank, 2008; Mohapatra & Mohanty, 2007; De, Dube & Prakasa Rao, 2005).

Farmers have not been maximizing crop production during *Rabi* cropping season due to rising surface air temperatures, rising sea surface temperatures, erratic out-of-season rainfall and unpredictable monsoon and post-monsoon seasons (Kalra et al., 2008; Jaswal, 2010; National Intelligence Council, 2009; The World Bank, 2008). *Rabi* means "spring" in Arabic and refers to the season in which the crop is harvested. Rabi crops are typically rain fed and planted just after the end of the monsoon season, in October. *Kharif* means "autumn" and refers to the harvest which is planted in July (National Informatics Centre, n.d.). Changing climate patterns have led to shifts in sowing time. In cases of shortened Rabi cropping season, increased timeliness of sowing is essential for a successful harvest (Jaswal, 2010; Kalra et al., 2008).

The state of Orissa is India's fifth largest rice producer of 19 producer states, after West Bengal, Andhra Pradesh, Uttar Pradesh and Punjab (International Rice Research Institute, 2009). Other major crops grown in the state include squash, pumpkin, millet, tomatoes, bitter gourd and potatoes (GoI, MoA, 2009). Orissa has among the lowest incidence of agricultural mechanization and the smallest average land holdings in the country (Alam, 2006). In the study area for this research, the average farmer held less than 1 acre of land.[1] Although each farmer is different, most agriculture is subsistence-based. Many farmers earn little cash income. They make ends meet during harvest time by selling crops or by doing non-agricultural labour outside of harvest time (RM, personal communication, 2010). Despite high subsidies offered by both state and national governments, it is not a priority for small farmers in Orissa to purchase machinery such as power tillers and tractors. Plots of land are small, uneven and often inaccessible by road making heavy machinery less efficient. Low cash flow requires small farmers to take out bank loans for major purchases, which is a financial risk.

Climate change responses include both adaptation and mitigation mechanisms. Adaptation to the adverse effects of climate change is required to reduce the effects of climate change visible now, while also increasing resilience for the future (UNFCCC, n.d.). Mitigation is required to limit

[1] In the case study location, land is measured in *bhorono*, roughly equivalent to 0.2 acres.

the amount of greenhouse gases (GHGs) released into the atmosphere from anthropogenic sources in order to minimize the extent of future climate change (Metz, Davidson, Bosch, Dave, & Meyer, 2007).

This research investigates one possible adaptation mechanism to impacts of climate change, that is, the potential for entrepreneurial farmers in Orissa to purchase machinery as individuals or in a group and to run a machinery-for-hire business in local villages. This kind of arrangement may allow smaller farmers to benefit from access to mechanized agriculture. As a mitigation mechanism, it is possible to produce biofuel from local and indigenous oilseeds in small Orissan villages with NGO partnerships and barefoot technicians. CTx GreEn, an NGO functioning in Mohuda, Orissa has been working since 2004 with several villages to press non-agricultural oil seeds on site manually and convert the oil to biofuel using a bicycle powered machine. This biodiesel can be used in any diesel engine with only simple modifications.

Biofuels may have potential to be used as an interim adaptation mechanism in cases where fossil fuel consumption is not yet present or is still very low. Localized biofuel production may allow communities to produce their own fuel to use in place of fossil fuel as required – necessarily keeping the scale of biofuel production and use in appropriate relationship to the size of the community. This model could function in any location where fossil fuel use is not widespread and where there are local, indigenous oilseeds that are relatively abundant and can produce an efficient fuel.

Current literature regarding both biofuel development and coping with changing climate is largely silent on the potential for local small-scale biofuel production as part of an integrated approach to climate change involving both mitigation mechanisms and adaptation strategies. In particular there is little literature examining case examples of implementation.[2] This research addresses that gap, using the case of Tamana, Orissa as an example of how such an enterprise could work. Specifically, this research investigates the potential of coupling machinery-for-hire businesses with local sustainable biodiesel production as one means of adapting to changing climate using mechanization and without contributing to rising GHG emissions. Project

[2] See Vaidyanathan, 2009 for one exception.

planning has predicted other positive impacts, including village level entrepreneurial support and development, local economic gains and increased community cohesion.

The case study presented here, of an 85 household village in Orissa, is useful because it allows for in-depth understanding of agricultural practices and rationale in an established context. While the discussions and findings of this research are specific to the case study village, it is expected that they may also have relevance for other villages in India, and for other remote agricultural settings in which subsistence farming remains a foundation for livelihoods, as a potential application of integrated mechanisms for coping with climate change from an agricultural perspective.

Literature regarding integrated approaches to climate change is growing as researchers and climate change policy makers begin to understand that mitigation mechanisms alone are not the solution (Ayers & Huq, 2009; Biesbroek, Swart, & van der Knaap, 2009; Rosensweig & Tubiello 2007; Tol 2005; Yohe & Strzepek 2007; Jones, Dettmann, Park, Rogers & White, 2007; Nyong, Adesina, & Elasha, 2007). The IPCC suggests that due to the emissions currently in the atmosphere, some level of climate warming is already expected and that emissions reductions are necessary to keep this warming to a minimum (Solomon et al., 2007). Adaptation responses have or will become requirements in the face of changing climates. Mitigation remains important to redress historic errors and to ensure that anthropogenic climate warming stabilizes in the near future (Metz et al., 2007). This study takes a localized, community based approach, offering one of the first village level case studies of integrated mechanisms for addressing climate change.

### 1.5. Background: Orissa, India

Orissa is a coastal state located in eastern India. It is bordered by West Bengal to the northeast, Jharkhand to the northwest, Chhattisgarh to the west and Andhra Pradesh to the south (see Figure 1). The Bay of Bengal affects state weather and rain patterns and makes it especially vulnerable to unpredictable weather events forming over the bay, including tornadoes, hurricanes and cyclones. The state occupies 4.74% of India's landmass.


(Adapted from http://www.maps-india.com/india, n.d.)

**Figure 1.** Maps of India and Orissa Indicating the Location of Case Study Site

The last official census of India was carried out in 2001 and will be renewed in 2011. According to the 2001 census, the population of Orissa was 36.7 million of a total Indian population of 1.03 billion (approximately 3.58 percent). The population of Orissa grew approximately 15.94 percent over 1991 levels and if this growth rate is taken as the same from 2001 to 2010, it is estimated that the current population of Orissa in 2010 is approximately 42.1 million (Mahapatra, 2004).[3] Population density in Orissa was 203 per sq. km in 1991, which increased to 236 per sq. km in 2001, still remaining lower than the all-India average of 313 per sq. km (GoI, Ministry of Home Affairs, 2001). Literacy rates grew considerably in the state between 1991 and 2001, from 49.10 percent to 63.08 percent respectively. Male and female literacy rates

[3] With a decadal growth rate of 15.94% one can speculate that the annual growth rate is equal to 15.94%/10 years which is equal to 1.594% growth/year. The range of 2001 to 2010 is only 9 years therefore the estimated growth rate is the average yearly growth rate times 9, or 1.594% x 9years, which equals 14.346%. The population in 2001 was approximately 36.7 million times 14.346%+1 equals an estimate of 42.1 million.

were recorded at 75.35 percent and 50.51 percent respectively in 2001, indicating that there is a significant gender divide in this area (GoI, MoHa, 2001).

The Gross State Domestic Product (GSDP) of Orissa was approximately Rs. 33,042.10 *crore* (Rs. 330 billion or 7.52 billion CAD) in 2005-06, which increased 4.93 percent above 1993-94 levels, at constant prices (where 1 *crore* is equal to 10 million). However, the Government of Orissa notes that this growth was not uniform over all years and is very dependent on monsoon reliability and natural calamities including drought (GoO DES, 2007). Close to 85 percent of Orissa's population lives in rural areas and relies on agriculture for livelihood (GoI, MoA, 2009). The agricultural sector provided 21.4 percent of GSDP in 2004-2005 (GoO, DAFP, 2008). The economic success of the state and the growth of GSDP are strongly connected with agricultural productivity. "Bad years" for GSDP are often due to drought, flooding or other natural disasters. In the six years from 2000 to 2006, three years were considered "bad years" by the Government of Orissa, while the year 2003-2004 recorded the highest growth (15.29 percent) over previous years, exemplifying the volatility of reliance on the agricultural sector (GoO, DES, 2007).

### 1.6. Thesis Organization

This thesis is divided into 7 chapters. The first chapter introduced the research question, objective and rationale and presented relevant background information. Chapter 2 is a literature review of various relevant topics including international regulation of climate change, climate change science, climate change in India and Orissa, mitigation versus adaptation to climate change, first and second generation biofuels, biofuels in India, sustainability assessments and a discussion of scales of biofuel production. Chapter 3 outlines the research methodology and describes the various stages carried out in Canada and India. Chapter 4 provides further context for the case study, including a review of agricultural mechanization and diesel consumption in Orissa and India. This chapter also addresses sustainable agriculture in India and scheduled castes and tribes in Orissa. Chapter 5 presents data from the case study of Tamana, Orissa and includes a village profile and a discussion of mechanization in agriculture. Chapter 6 compares two scales of biodiesel production in Orissa, one village-based and one mid-sized, both producing biodiesel for different purposes. Finally, chapter 7 concludes the thesis and ties together the information presented in chapters 1 to 6.

# 2. Review of Academic Literature and Grey Material

## 2.1. Climate Change: Global Implications

The prominent international organization at the head of the climate change debate is the Intergovernmental Panel on Climate Change (IPCC). In 1992, meetings of IPCC member nations led to the implementation of an international treaty governing climate change, called the United Nations Framework Convention on Climate Change (UNFCCC). Other chief international organizations such as the United Nations Development Program (UNDP), the World Meteorological Organization (WMO), the World Bank (WB) and the United Nations Educational Scientific and Cultural Organization (UNESCO) have released reports regarding changing climate (UNDP, n.d.; WMO, n.d.; WB, 2010; UNESCO, 2010). Civil society groups, academia and NGOs have also addressed the issue of climate change, for example Canada's Pembina Institute, Nicholas Stern on behalf of the British Government, and the Climate Action Network (The Pembina Institute, n.d.; Stern, 2006; Climate Action Network, n.d.).

### *2.1.1. Defining "Climate Change"*

The UNFCCC defines "climate change" as a "change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability over comparable time periods" (UNFCCC, n.d.). This differs from the IPCC definition of climate change as "…any change in climate over time, whether due to natural variability or as a result of human activity" (Parry et al., 2007, p.21). For the purpose of this research, the latter definition of climate change is applied.

The IPCC established in its Fourth Assessment Report (AR4) that past and current global output of anthropogenic GHGs will lead to a 0.2°C temperature increase per decade over the next 20 years if unabated (UNFCCC, 2009a). There will be significantly more increase if GHG emissions continue to grow beyond current levels. The IPCC also considered that "[a]nthropogenic warming and sea level rise would continue for centuries due to the time scales associated with climate processes and feedbacks, even if greenhouse gas concentrations were to be stabilized" (Solomon et al., 2007, p.16; IEA, 2009).

GHGs refer to the atmospheric gases responsible for causing global warming and changing climate patterns. The major GHGs of concern are water vapour, carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O). Less prevalent, but very powerful in their impacts are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6) (IEA, 2009; UNFCCC, 2009b).

### *2.1.2. Intergovernmental Panel on Climate Change*

The IPCC was created in 1989 by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to provide governments with a clear scientific view of changing climate patterns (IPCC, 2010a). The role of the IPCC is to "assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation" (IPCC, 2010a). The IPCC claims a politically neutral standing and does not make policy recommendations. Scientists contribute to the work of the IPCC on a voluntary basis and are not employed by the organization as researchers.

The organization is divided into three working groups which assess respectively "The Physical Science Basis", "Climate Change Impacts, Adaptation and Vulnerability", and "Mitigation of Climate Change." In addition there is a "Task Force on National Greenhouse Gas Inventories", which aims to record and assess levels of GHGs in the atmosphere (IPCC, 2010a). The IPCC releases reports on various scientific topics related to climate change but its most notable publications are the IPCC Assessment Reports, which offer the most comprehensive compilation of climate science available. The IPCC has released four Assessment Reports to date, the first in 1990 and the most recent in 2007. A fifth report is planned for 2014 (IPCC, 2010a).

### *2.1.3. Critiques of the IPCC*

A major critique of the IPCC is that it relies on non-original research and instead seeks to compile and summarize the work of others in the field of climate science. The IPCC's inclusion of "grey material" (such as newspapers, government policies and NGO documents) in its assessments has been the subject of media attention (Pearce, 2010b). After the release of the AR4, there was concern that the projected date for the melting of the Himalayan glaciers presented in the Summary Report is incorrect, leading to widespread media attention over the soundness of the whole report (Adam, 2010; Pearce, 2010a; Bagla, 2009). In January 2010, the IPCC released a statement indicating that in the case of the data presented in the paragraph under scrutiny, "the clear and well-established standards of evidence, required by the IPCC procedures, were not applied properly". The IPCC maintained in the same statement that the general conclusion on the retreat of the Himalayan glaciers "is robust, appropriate, and entirely consistent with the underlying science and the broader IPCC assessment" that the Himalayan glaciers are in danger of melting (IPCC, 2010b).

#### *2.1.4. United Nations Framework Convention on Climate Change*

The First Assessment Report of the IPCC released in 1990 contained the findings of 400 scientists and claimed that climate change was a scientific reality and that global action was required. As a result, governments agreed on the UNFCCC, an international treaty that was negotiated and signed at the 1992 United Nations Conference on Environment and Development in Rio de Janeiro, Brazil (UNFCCC, n.d.). The convention entered into force in 1994 and currently has 83 signatories and 191 parties (190 states and one regional economic integration organization) (UNFCCC, n.d.). The Convention itself does set any binding targets for nations to reduce emissions.

The UNFCCC has held a Conference of the Parties (COP) every year since 1995. The Kyoto Protocol was adopted in 1997 during the third COP in Kyoto, Japan. It came into force in 2005 and "sets binding targets for 37 industrialized countries and the European community for reducing greenhouse gas (GHG) emissions" (UNFCCC, n.d.).

### *2.1.5. The Kyoto Protocol*

There are three internationally mandated market-based mechanisms under the Kyoto Protocol that are meant to supplement domestic emission reductions. These include International Emissions Trading (IET) or a carbon market, Joint Implementation (JI) and the Clean Development Mechanism (CDM). IET is an allowance based transaction system that operates at the country level in which nations can trade amongst themselves to achieve their carbon emission reductions (Woerdman, 2000). The JI system allows developed countries to purchase carbon credits from other developed countries (specifically the former Soviet Bloc) via project-based transactions. These credits are referred to as Emission Reduction Units (ERUs) (Young, S., personal communication, 2008; Woerdman, 2000). CDM is similar to JI but it operates between developed and developing countries using project-based transactions. Once registered and approved under the CDM, these carbon offsets are referred to as Certified Emissions Reductions (CERs) (Woerdman, 2000). The Kyoto Protocol also established an Adaptation Fund "…to finance concrete adaptation projects and programmes in developing country Parties to the Kyoto Protocol that are particularly vulnerable to the adverse effects of climate change" (UNFCCC, n.d.). The Fund is financed by a share of proceeds from CDM activities amounting to 2 percent of CERs (UNFCCC, n.d.). Other funds established under the protocol include the Special Climate Change Fund (SCCF) for adaptation, technology transfer and capacity building, and the Least Developed Countries Fund (LDCF) to assist Least Developed Country Parties (LDCs) with adaptation mechanisms (UNFCCC, n.d.).

As of 2010, the Kyoto protocol has 84 signatories and 191 parties. The United States (US) has not ratified the protocol but is the world's second highest emitter after China. The US was responsible for 16% of total global emissions in 2006 (Netherlands Environmental Assessment Agency, 2007; UNFCCC, n.d.). China signed and ratified in 1998, while India has ratified but not yet signed the treaty. The protocol expires in 2012, before which a new international framework must be negotiated and ratified by all signatory parties at the remaining COP meetings. The next COP will take place in December 2010 in Mexico.

### *2.1.6. COP15: Copenhagen, Denmark*

The UNFCCC 15th Conference of Parties (COP15) under the Kyoto Protocol took place in December 2009 in Copenhagen in a context of great controversy. Before it began, it was recognized by policy makers, NGOs and informed citizenry for the potential to produce a legally binding global decision on climate change (Demerse & Bramley, 2009; Climate Action Network Canada, n.d.). Instead, the Copenhagen accord has been criticized as vague, non-binding and most of all, not fully inclusive. It was drafted by just a few nations, including the US, China, India, and South Africa, all of which are among the world's top emitters (Demerse, 2009; Brisby, 2009; Goma, 2009).

The Copenhagen Accord recognizes that there is a need to keep global warming within 2°C above the pre-industrial level. However, the Accord offers no legally binding method for this to be ensured (UNFCCC, 2010). Since January 2010, countries responsible for over 80 percent of greenhouse gas emissions have engaged with the Copenhagen Accord and pledged emissions reductions. Pledges to reduce emissions by 2020 include China at 40-45 percent, the US at 17 percent and India at 20-25 percent (United States Climate Action Network, 2010).

There are several groupings of countries that are opposed to and critical of the accord, and these include many African nations and the Small Island Developing States (SIDS). In the case of the latter, climate change research presented by the IPCC Working Group II indicated in the AR4 that a change in global temperature of 1°C could lead to damaging sea level rise, changes in rainfall and damage to ecosystems that could render small islands socially and economically unsound places to live (Parry, et al., 2007, p.689).

## 2.2. India on Climate Change

The Indian Prime Minister's Council on Climate Change (PMCCC) was inaugurated in 2007. Thereafter, the Indian Ministry of Water Resources (MoWR) was tasked with assessing the effects of climate change on water systems in India (GoI, Ministry of Water Resources, 2008). In 2008, the Council released the National Action Plan on Climate Change (NAPCC), outlining eight national missions and their implementation through to the year 2017 (the end of India's 12th

Plan period) (GoI, PMCCC, 2008). The missions include: National Solar Mission, National Mission for Enhanced Energy Efficiency, National Mission on Sustainable Habitat, National Water Mission, National Mission for Sustaining the Himalayan Ecosystem, National Mission for a "Green India", National Mission for Sustainable Agriculture, and National Mission on Strategic Knowledge of Climate Change (GoI, PMCCC 2008). The NAPCC outlines timelines to achieve each mission and indicates which government ministries will oversee the progress. However, there are critics of the Plan. Members of civil society and NGOs believe the Plan was produced through an undemocratic process and did not involve any contributions from civil society (Thakkar, 2009; Climate Leaders, 2010). According to critics, the "NAPCC lacks proper perspective, urgency and sincerity in taking note of contributions of various sectors and classes in India's current and future emissions" (Thakkar, 2009, p. 7). Specifically, Thakkar (2009) is opposed to India's position that it will continue to sustain its economic growth to meet levels of industrialization achieved in the developed world despite changing climate concerns. Rapid growth of the Indian economy has shown greater marginalization of the poor while the benefits of development have gone largely to the elite (Thakkar, 2009). The NAPCC was a positive move in India's climate change policy as it clearly stated and recognized the importance of climate change; however it also solidified India's position that it is not willing to sacrifice development to address climate change.

### *2.2.1. India at Copenhagen*

India's position at Copenhagen was outlined by the Government of India Public Diplomacy Division of the Ministry of External Affairs (MoEA) in February 2009. The position was presented in question and answer format on India's view of climate change and its role in the UNFCCC process. In the statement, India indicates (summarised from GoI, MoEA, 2009, p.3-8):

- While it is the third largest emitter of GHGs, it has lower per capita emissions than the two largest emitters, the US and China (In 2009 India's per capita emissions were 1.1 tonnes, compared to 20 tonnes in the US and 10 tonnes in other OECD countries).
- Anthropogenic climate change is a result of cumulative GHGs already in the atmosphere and these are due to the historical industrialization of developed nations. India supports

the UNFCCC position that industrialized nations should make drastic emission cuts but developing countries are not bound to do the same.

- The Kyoto Protocol only sets targets for developed countries but India has declared, "even as it pursues its social and economic development objectives, it will not allow its per capita GHG emissions to exceed the average per capita emissions of the developed countries" (p. 3).
- Climate change cannot be focused only on reducing emissions but adaptation must also be addressed. India is already spending 2% of its GDP on adaptation, a figure it expects to rise.
- The Copenhagen outcome must be concluded with equity in mind, "recognizing that every citizen of the globe has an equal entitlement to the planetary atmospheric resource" (p. 5).
- The principle of equity recognizes that over time average per capita emissions should converge.
- The Copenhagen Accord should (p. 6-7):
    - Commit developed countries to significant reductions in their GHG emissions;
    - Achieve the widest possible dissemination of existing climate-friendly technologies and practices; and
    - Put in place a collaborative R&D effort among developed and major developing countries, to bring about cost-effective technological innovations and transformational technologies that can put the world on the road to a carbon-free economy.
- Elements of India's NAPCC should not be used in global climate negotiations to bind India to its own domestic plan because "subjecting national aspirational efforts to an international compliance regime may result in lower ambitions" (p. 10). National action plans are also financially supported using domestic sources, rather than an international regime, which should be supported by the international community.
- India opposes the imposition of "sectoral targets" for carbon and energy intensive industries, as these will increase protectionism. It will also be inconsistent cross-nationally as there are different technologies and mechanisms in use even within the same industry. Climate change negotiations should remain focused on addressing climate

change and should not "impose conditionalities or additional burdens on developing countries" (p. 11).

- India believes that addressing climate change should become part of a global economic upturn and should support economic development rather than hinder it.

The Indian Prime Minister's special envoy on climate change, Shyam Saran, recognized in 2009 and 2010 that climate change is a national and global concern that should be addressed (GoI MoEA, 2009; Saran, 2009; Saran, 2010). Saran endeavoured to resolve the notion that India is refusing to reduce its emissions. In a speech to the Vivekananda International Foundation on March 19, 2010, Saran explained that the onus lies with developed nations to take larger emission cuts and support developing nations financially to move away from fossil fuel dependence. This financial support should be detailed in a global accord and should be over and above currently allocated aid. Finally, India will continue to follow its domestic missions outlined in the NAPCC, which it feels is an adequate national response to climate issues (Saran, 2010). On March 14, 2010, Saran resigned from his position as the Prime Minister's special envoy on climate, allegedly over disagreements on India's climate change position with the Indian Environment Minister, Jairam Ramesh (The Times of India, 2010).

### 2.3. Changing Climate or Climate Change?

India is a large country with varied climate patterns from north to south and east to west (The World Bank, 2008). A January winter day in northern Srinagar can have a maximum temperature of 4.7°C, while on the same day in the southern state of Kerala temperatures can reach almost 32°C (WMO, n.d.). Despite these regional weather variations, the southwest monsoon, which forms over the Bay of Bengal, affects the country as a whole from June to September (India Meteorological Department, n.d.).

The monsoon is defined by the India Meteorological Department (IMD) as a seasonal reversal of winds and its associated rainfall (n.d.). It is caused by the annual oscillation of the sun between the Tropics of Cancer and Capricorn, which cause an oscillation of temperature, pressure, wind and rain on the surface of the earth (IMD, n.d.; American Meteorological Society, 2000). The

southwest monsoon occurs in two parts, one arm reaching the south western state of Kerala around the beginning of June and a second arm arriving over Tamil Nadu, Andhra Pradesh and Orissa. The monsoon rains dictate many things in India, including agricultural success. Not only can monsoon rains fail to be substantial but too much or severely erratic rain can be equally damaging (The World Bank, 2008; TERI, 2009; British Broadcasting Corporation, n.d.).
Changing monsoon patterns are not the only important climate change issue facing India. Shortened seasons (including the rabi season), declining coastlines and increased incidences of extreme weather events also weigh heavily. There is also concern about rising daytime and night time temperatures both of which affect the growth of crops and impact regional rain patterns (GoI, MoA, 2009).

Climate is inherently variable from year to year and many scientists and analysts have established that changing climate patterns over a period of thousands of years is normal (Pearson & Palmer, 2000). However, the climate change that has occurred in the 20$^{th}$ century has been much faster than ever before documented by scientific analysis, and atmospheric $CO_2$ levels have grown exponentially (Stern, 2006). Figure 2 shows changes in atmospheric $CO_2$ from 647,000 BC to 2006. This figure, based on data from the Environmental Protection Agency, indicates that while $CO_2$ fluctuations are not historically unprecedented, the very rapid increase in emissions in the last two decades until 2007 is concerning. Temperature changes follow a similar pattern and also show a steep increase over the two decades leading up to 2007 and are much higher in these two decades as compared to the rest of the data years. The information presented in the figure below is a compilation of data from various academic sources primarily relying on ice core records to establish levels of atmospheric $CO_2$ over millennia (United States Environmental Protection Agency, 2009).

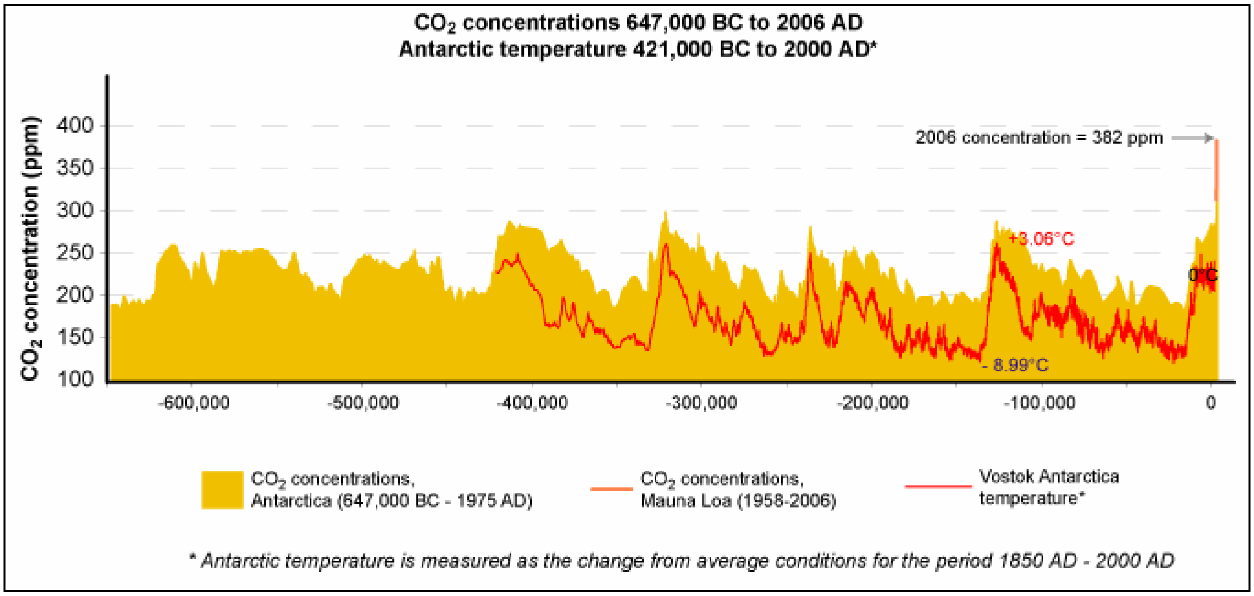



**Figure 2.** Historical atmosphere $CO_2$ concentrations.

*Fluctuations in temperature (red line) and in the atmospheric concentration of carbon dioxide (yellow) over the past 649,000 years. The vertical red bar at the end is the increase in atmospheric carbon dioxide levels over the past two centuries and before 2007 (reproduced from United States Environmental Protection Agency, 2009).*

According to the IPCC AR4, climate has increased by 0.74°C in the last hundred years with the bulk of the warming occurring in the last 50 years. Temperatures rose at a rate of approximately 0.13°C per decade from 1956 to 2005 (Solomon et al., 2007). Current predictions suggest that the world is facing an average temperature rise of 3°C during the twenty-first century if emissions continue to rise at their current pace and greenhouse gas concentrations are allowed to double from their pre-industrial level (UNFCC, 2009a; Solomon et al., 2007).

## 2.4. Climate Change in Orissa

The IPCC has recognized the vulnerability of coastal and low-lying areas to climate change. Orissa is located on the east coast of India and is historically prone to natural disasters including hurricanes and cyclones, the frequencies of which are expected to increase with climate warming according to the IPCC AR4 (Parry et al., 2007). "Orissa is among the most flood-affected states in the country […] frequently it has coped with simultaneous droughts in one part of the state and extensive floods in another" (The World Bank, 2008, p. 10). Coasts are likely to see erosion due to sea-level rise, which will be exacerbated by increasing human-induced pressures on coastal areas. Finally,

> Many millions more people are projected to experience severe flooding every year due to sea-level rise by the 2080s. Those densely-populated and low-lying areas where adaptive capacity is relatively low, and which already face other challenges such as tropical storms or local coastal subsidence, are especially at risk. The numbers affected will be largest in the mega-deltas of Asia and Africa, while small islands are especially vulnerable (UNFCCC, 2009a, p. 3).

The potential impacts of these events include human and animal deaths, loss of infrastructure and housing, loss of livelihoods and loss of cropland due to flooding, drought and erosion. The super cyclone of 1999 which affected Orissa and West Bengal killed 198 people and injured 402, while severely crippling the economic development of these states in 1999 and 2000 (Centre for Research on the Epidemiology of Disasters, 2009; The World Bank, 2008; GoI, MoA, DoAC, 2009). The UNDP estimates that Orissa endured over 11,000 extreme weather events and natural disasters between 1970 and 2007, involving over 54,000 deaths and 1.6 million destroyed houses (CRED, 2009). Climate change concerns validated by the IPCC AR4 indicate that areas like Orissa will become more susceptible to extreme weather events with changing climate patterns, which will add social and economic pressure to the state.

**Box 1. Defining Vulnerability**

> The effects of climate change differ among regions but the IPCC has identified several areas as "highly vulnerable". Vulnerability is defined generally as "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes" (Parry et al., 2007, p.21). These include the Arctic, Africa, Small Island Developing States (SIDS), Asian mega deltas and the Himalayan glacier melt. For the purpose of this study, the Asian mega deltas include the Ganges-Brahmaputra delta, which flows between Bangladesh and the state of West Bengal, India, located just above the case study state of Orissa. The vulnerability of the delta comes from large populations living in the area that are highly exposed to sea-level rise, storm surge and river flooding (UNFCCC, 2009a).

## 2.5. Mitigation vs. Adaptation

Both mitigation of, and adaptation to, climate change are important, however they have not received equal attention in climate change debates (Dang, Michaelowa & Tuan, 2003). Prior to the Third Assessment Report (TAR) of the IPCC released in 2001, focus was mainly on mitigation. It was in the TAR that the IPCC began to imply that adaptation is a fundamental concern, primarily for developing countries (Ahmad et al., 2001).

Proposals for and debates about mitigation strategies have dominated climate change discussions since the implementation of the Kyoto Protocol in 2007, focusing most notably on carbon trading and carbon sequestration approaches (Wismer & Dabby, 2009). Carbon trading is a preferred option among governments as it gives economic value to carbon and seeks to commodify GHG reductions. In a carbon trade atmosphere, emitters are given incentives to offset their emissions by purchasing "carbon credits" from others who are cutting emissions or sequestering carbon from the atmosphere. Many third party organizations have emerged to offer extra-governmental ways for individuals and organizations in the developed world to offset carbon footprints by supporting initiatives such as tree plantations, methane capture and storage and biomass cookstoves (Plan Vivo, 2010; ClimatePath, 2010). Carbon sequestration is the process of increasing plant matter, primarily in the form of fast growing trees that can absorb $CO_2$ from the atmosphere. In other words, it is an attempt to create forests that can act as carbon sinks. Both practices have drawbacks. The success of carbon trading is rooted in its methods of evaluating emissions reductions, which as of 2010 have not been standardized across the globe. Carbon sequestration is difficult to quantify and varies by tree species. Sequestration is also negated if trees are destroyed by fire or other natural calamities.

Adaptation strategies for climate change were less promoted than mitigation mechanisms before the release of the TAR in 2001. This may be because adaptation mechanisms are less marketable and do not offer easy "carbon credit" financing. The IPCC AR4 recognized that currently adaptation is occurring "to a very limited extent" and that more extensive adaptation is required (UNFCCC, 2009b, p. 3). Future vulnerability of various regions will depend not only on climate change but also on chosen paths to development.

Linking mitigation measures and adaptation strategies for climate change is a relatively new approach, which also emerged post TAR (Dang, Michaelowa & Tuan, 2003). Various authors have written about the benefits of integrating mitigation and adaptation for climate change, including Wilbanks, Kane & Leiby (2003), Rosenzweig & Tubiello (2007), Dang, Michaelowa & Tuan (2003) and Michaelowa (2001).

### 2.6. IPCC Special Report on Emission Scenarios

The IPCC Special Report on Emission Scenarios outlines six global scenarios under changing climate patterns. The scenarios take into consideration aspects such as global economic growth, sources of energy, global fertility and family income (Solomon et al., 2007). None of the scenarios assume the implementation of the UNFCCC or the Kyoto Protocol. When these scenarios are compared, the scenario with an emphasis on a "rapid change in economic structures towards a service and information economy with reductions in material intensity and the introduction of clean and efficient-resource technologies" results in the lowest level of global surface warming by 2100 (Solomon et al., 2007, p. 14-18). The importance of *clean and efficient-resource technologies* in this scenario highlights the need to investigate non-fossil fuel energy sources for the future.

### 2.7. Bio-fuelling Sustainable Development

Biofuels have received added attention in the last forty years, as climate change science and "sustainable development" have gained importance globally (Heintzman & Solomon, 2009). The notion of sustainability has figured in policy discussions since the early 1970s. Gibson (2006) maintains that the "idea of sustainability arose in response to the spreading gulf between rich and poor and the continued degradation of biospheric systems" (p. 171). There were a series of attempts to adequately define the term, notably at the United Nations 1972 Stockholm Conference on the Human Environment. In 1983, the Brundtland Commission was created to deal with "the tensions that had arisen at Stockholm" (Gibson, Hassan, Holtz, Tansey & Whitelaw, 2005, p. 48). The now-famous Brundtland Commission report "Our Common Future" was released in 1987 and offered the most widely accepted definition of "sustainable development" to date. It is defined as: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland Commission, 1987, Ch. 2). Defining the concepts of sustainability and sustainable development began a concerted discussion on the unsustainable nature of growth in the 20$^{th}$ and 21$^{st}$ centuries and the increasing global dependency on fossil fuel.

The inventor of the diesel engine, Rudolf Diesel, is known to have experimented with plant oils as a fuel source. In the Paris Exhibition of 1900, peanut oil was used successfully in a diesel engine meant for petroleum with no modifications (Knothe, Van Gerpen, & Krahl, 2005). Despite the potential of straight plant oil to be used successfully as a fuel, the cost associated with collection, pressing and sale of plant oils was much higher than for petroleum at the turn of the 20$^{th}$ century. It was not until the energy crisis of the 1970s that interest in fuel from plant sources was renewed in the face of rising oil prices (Knothe et al., 2005; Altenburg et al., 2008). Biofuels were seen as a "renewable" source of energy: plant and woody matter can be regenerated over decades while fossil fuels form over millennia.

Altenburg et al. (2009) note that "[i]n view of rising prices and the environmental – and primarily climate-change – concerns that result from increased global energy consumption, countries all over the world have launched biofuel programmes to develop alternatives to conventional fuels" (p. 13). Climate science has established that global warming is a real concern and that there is a need to cut consumption of fossil fuels to limit global warming to its least damaging levels. In light of this, governments, NGOs and individuals are searching for more sustainable alternatives to fossil fuel consumption, but there is still an overwhelming desire to maintain a high standard of consumption and strong economic development.

Biofuel production for industrial use has proliferated, primarily in developing countries like Brazil, Malaysia and Indonesia (Ernsting, 2007). Several governments including the United States and the European Union have mandated that up to ten percent of fuel inputs should come from biofuels within the next ten to twenty years (Rajagopal & Zilberman, 2007), further driving up demand for industrially produced biofuel. India has followed suit, indicating in its National Biodiesel Policy a desire to achieve 20 percent blending of biofuel by 2017 (GoI, MNRE, 2008).

Canada has mandated five percent blending of renewable fuel in gasoline by September 2010 and two percent blending in diesel fuel by 2012 (Government of Canada, Department of the Environment, 2009). This is a much lower blending mandate than the US, EU and India, but according to Reuters, Canada's domestic production of renewable fuel will still fall short of achieving these goals (Nickel, 2009). Canadian biofuel manufacturers currently produce ethanol from corn and wheat, and biodiesel from animal fat, soybeans and canola (Government of Canada, Department of the Environment, 2009).

#### *2.7.1. Biofuels in Controversy*

Despite their appeal as an alternative to fossil fuels, biofuels are the subject of considerable controversy. The primary concern is that the growth of agricultural crops to produce biofuels may be inherently unsustainable (Peer et al., 2008). This is because crops require land and water to grow no matter what their end use. As interests in biofuels rise, farmers have financial incentives to move from producing food crops to fuel crops. Crops of any nature in industrialized agriculture require synthetic inputs such as fertilizers and pesticides, both of which are produced and transported using fossil fuel energy. This fact adds to the overall energy required to produce crops that provide energy and raises questions about whether the finished product provides more energy than is spent to produce it (Giampietro, Ulgiati & Pimentel, 1997). Plus, industrial agriculture of all types tends to generate environmental impacts of concern such as land use change, soil erosion, water source contamination and unsatisfactory worker health and safety conditions (Puppán, 2003). Cutting down rainforest and filling in wetlands in order to grow biofuel crops is happening across the developing world, primarily in Indonesia where private companies have burned rainforest in order to plant palm oil plantations (OECD & FAO, 2008; Ernsting, 2007). There is an ongoing debate about the effects of this type of land use change on GHG emissions. It is unclear whether the end fuel product will truly be better for the environment than fossil fuels when subjected to a Life Cycle Analysis (LCA) (Heintzman & Solomon, 2009; Puppán 2003). LCA is defined by the International Standards Organization (ISO) as "a compilation and evaluation of inputs, outputs and potential environmental impacts of a products system throughout its life cycle" (cited in Guinée et al., 2001).

There is evidence that burning biofuels emits less carbon dioxide ($CO_2$) than fossil fuels, but in some cases emissions of nitrogen oxides ($NO_x$) may increase, depending on the source of the fuel (Knothe et al., 2005; Kemp, 2006). Also, all oils have a different chemical composition which leads to varied emission levels upon combustion. To meet this academic and policy concern, studies on the environmental impacts of different biodiesel sources have emerged, such as Puppán (2002) and the United States Environmental Protection Agency (2002). Similarly, LCAs for potential biodiesel source oils are available, such as Jatropha in Thailand by Preuksakorn & Gheewala (2008) and Jatropha in India by Whitaker & Heath (2010).

Fossil fuels are used in many industrial biofuel production processes, potentially nullifying the reduction in emissions from burning biofuels. This can be mitigated if the sources for biofuels are changed, for example away from feedstock and towards waste vegetable oil or if the scale of production is reduced to a non-industrialized level (Chhetri & Islam, 2008). Waste vegetable oil requires filtration which can be done with simple machinery, depending on the scale of production. Reducing the scale of biofuel production altogether eliminates the need for heavy machinery that runs on fossil fuel, for example transportation trucks. One option is using human pedal power to press oil from seeds and to convert oil into biofuel rather than relying on electricity or crude oil to power machinery (CTx GreEn, 2009).

A secondary concern is whether an increase in industrial biofuel production will negatively affect food security, particularly for the urban poor (Altenburg et al., 2008). In the case of the US, the EU and Brazil, the primary sources of biofuels (both produced and consumed) are edible crops including corn, soy and palm oil (FAO, 2008). When these crops are grown and purchased for biofuel production, they are removed from food production, thus decreasing the supply of food worldwide (Weis, 2007). In market terms, a decrease in supply is always met with an increase in price. This exacerbates an already existent situation where demand for food exceeds supply, propelled by a growing global middle class (primarily in China and India) and a steadily rising global population (Weis, 2007). Most affected are the urban poor who spend the bulk of their income (up to 90 percent) to feed their families (Heintzman & Solomon, 2009). Next affected are the rural poor who may produce some food for subsistence purposes but, due to increased pressure to convert subsistence plots to monocrop or cash crops (including corn and soy for biofuels) farmers are increasingly forced to purchase part of their food (Weis, 2007). Therefore, farmers may accrue a higher income from the sale of their crops, but they will be forced to pay more for the food that they must purchase to supplement their diets (Altenburg et al., 2008).

A final concern is that agricultural land availability will suffer due to increased production of biofuels on an industrial scale. This will intensify the food versus fuel effects given that there will be less agriculturally prime land available to grow food crops if these lands are overtaken by biofuel crops (FAO, 2008). Moving crop production from food to fuel may be seen by farmers as more economically lucrative if the price for biofuels increases on the world market to a level even higher than food prices (FAO, 2008). This is especially true if the sources of the biofuels are the crops already being grown on their fields, as in the case of corn, soy, or sugarcane, where farmers only have to change the industry they sell to and not the crops they produce.

### *2.7.2. Which Biofuel?*

Beyond these three important concerns there is a new issue on the table – what is the best source for biofuels? Given that sources such as corn, soy and palm oil are all edible, there is strong support for the concerns raised in the food versus fuel debate. To counter this, a push towards producing biofuels from non-edible sources has begun, from *Jatropha curcas* and *Pongammia pinnata* in Africa and India, for example (Altenburg et al., 2008; FAO, 2008). These fuel sources, however, are still subject to the other two concerns: increasing GHG emissions from production and land availability and inputs.

Second generation biofuels produced from lignocellulosic sources and high efficiency micro-algae have emerged to tackle these remaining concerns. Producing biofuels from short rotation woody mass and perennial herbaceous grasses moved the biofuel debate away from food crops into non-edible plant matter (Berndes, Azar, Kaberger, & Abrahamson, 2001). However, it is biofuel produced from salt water algae that has generated the most interest, particularly because algae hold an immense amount of oil that can be chemically transformed into biodiesel (Schenk et al., 2008). The argument holds that algae produce significantly more energy than their first generation predecessors (corn, soy, Jatropha and other oil seeds) but they also do not require as many agricultural inputs (Schenk et al., 2008; FAO, 2008). Briggs (2004) of the University of New Hampshire calculates that all the transportation fuel used in 2004 in the US could have been replaced using 9.5 million acres of land to produce 141 billion gallons of algae-based biofuel. That is just a little over two percent of the 450 million acres used in the same year for crop farming in the US. Briggs (2004) notes, however, algal biofuel production involves high evaporation rates of saltwater, especially in desert ponds, as well as high salt buildup, both of which come with their own set of concerns.

## 2.8. Biofuels in India

Current literature on biofuels in India is limited to examinations of large-scale production of ethanol and biodiesel, with the most comprehensive analyses coming from Gonsalves (2006) and Altenburg et al. (2008). Five state governments in India, being Karnataka, Tamil Nadu, Andhra Pradesh, Uttarakhand and Chhattisgarh have taken recent direct action to promote biofuels by introducing state-wide biofuel policies (Altenburg et al., 2008). A draft biodiesel policy written by the Government of India's Ministry of New and Renewable Energy (MNRE) was approved by the Indian Cabinet Committee in September 2008 but was not officially announced until December 2009 (BS Reporter, 2009). Key features of the policy are to (GoI, MNRE, 2008):

- Aim for an indicative target of 20 percent blending of petrol and diesel with bio-fuels by 2017.
- Promote biodiesel production from non-edible oilseeds in waste/degraded/marginal lands.
- Discourage plantations in fertile, irrigated premium farm land.
- Focus on domestic production of bio-diesel feed stock and not permit imports.
- Recommend minimum support prices for bio-fuel crops like Jatropha and other non-edible oilseeds with provisions of periodic revisions.
- Recommend a minimum purchase price for the purchase of ethanol based on the cost of production and import price. The biodiesel price will be based on the prevailing price of diesel.
- Take steps to ensure unrestricted movement of bio-fuels within and outside states.
- Removal of taxes and duties on bio-diesel.

- Set up of an inter-ministerial National Bio-fuel Coordination Committee under the Chairmanship of the Prime Minister and a Bio-fuel Steering Committee under the Chairmanship of the Cabinet Secretary for high level coordination and policy guidance or review on various aspects of bio-fuels development in India.

The National Biodiesel Policy seeks to promote domestic production and consumption of biodiesel in order to reduce its dependence on imported fossil fuel (GoI, MNRE, 2008; BS Reporter, 2009). " 'The Indian approach to biofuels is based solely on non-food feedstock to be raised on degraded or waste lands that are not suitable for agriculture, thus avoiding a possible conflict of fuel versus food security,'" according to the MNRE (BS Reporter, 2009). The high target set in the Policy of 20 percent blending by 2017 will require large-scale biofuel production in order to be met. This is supported by the government's approach to processing and fuel blending, which will require economies of scale to be successful. There is no direct mention of the scale of production of biofuel in the policy, but the provisions inherently support a larger, industrialized biofuel production system.

Altenburg et al. (2008) maintain that in the case of India, biofuels offer an opportunity to support the rural economy with cash crops. Biofuel production and processing may also provide jobs and income to India's rural poor, who make up over 60 percent of the workforce (Altenburg et al., 2008; Gonsalves, 2006). Secondly, they argue that biofuels offer an opportunity for energy autonomy, as India's oil imports have increased dramatically since 1991. India imports oil despite its own reserves, including 775 million tonnes of crude oil and 1074 billion cubic metres of natural gas (as on April 1, 2009) (GoI, MPNG, 2009a). In 2008-2009, India consumed 160.77 million tonnes of crude oil and 31.77 billion cubic metres of natural gas (GoI, MPNG, 2009b). At this rate, India will consume all of its crude oil reserves in 4.82 years and all of its natural gas reserves in 33.8 years. India imported 99.4 million tonnes of crude oil in 2005-2006, which increased to 121.7 million tonnes in 2007-08 and 128.2 million tonnes in 2008-2009 (provisional gross imports) (GoI, MPNG, 2009a). This represents an increase of 29 percent over three years. This increase in imports coupled with the drastic increase in the price of oil in the past fifteen years has taken a toll on India's foreign exchange (Gonsalves, 2006). Producing biofuels at home may offer some energy self-sufficiency to the country of over 1 billion. Producing and using biofuels will also help India reduce its GHG emissions, which are among the highest in the world, behind the US and China (Sharma, Singh & Panesar, 2006).

Biofuel production in India has been primarily focused on a few non-edible oilseeds, the most important being *Jatropha Curcas* and *Pongammia Pinnata* (also called Karanja). Neem is also being used in some cases. Altenburg et al. (2008; 2009) report that there is little economic viability in promoting India's industrial production of biofuels for domestic use given the current lack of economies of scale and the resulting high price of production. This assessment comes into direct conflict with India's mandate of 20 percent blending by 2017, indicating that India will have to work hard to produce the requisite amount of domestic biofuel to meet its goals.

Currently, several nationally sanctioned projects involving biofuels are underway in India according to The Energy and Resources Institute (TERI) (2009). The Government of India has plans to raise Jatropha and Pongammia crops on 0.2 million acres of wasteland in Andhra Pradesh for biofuel production. India's first biodiesel plant with a capacity of 30 tonnes per day is being set up in Kakinada, Andhra Pradesh on 50 acres of land, in collaboration with Austria's Energea GmbH and the US based Fe Clean Energy Group Inc. The Central Salt and Marine Chemicals Research Institute in Gujarat has engaged in a five-year partnership with automobile producer Daimler Chrysler to use biodiesel from Jatropha in their cars. Finally, over 60 electric generators running on Karanja oil are in use in villages in Karnataka, under the mandate of the Indian Institute of Science in Bangalore. The Government of India's Ministry of New and Renewable Energy is also engaged in several studies on biofuel policy issues (TERI, 2009).

### 2.9. Sustainability Assessments

There are limited analyses of sustainable energy production at the community level, with the most relevant to this study coming from Khan, Chhetri & Islam (2007). Sustainability assessments (SA) grew out of successful environmental impact assessments (EIA) and strategic impact assessments (SEA). While very similar to these processes, SAs seek to provide direct planning and decision-making towards a sustainable end. This approach has drawn much academic and policy-based interest in the last decade (Gibson, 2006). As they become more popular, various governments, private firms and other organizations have begun implementing SAs into their practices. Examples include the Forest Stewardship Council, the UNDP and the Canadian assessment of the Voisey's Bay nickel mine (Gibson, 2006).

Criteria and processes for a successful sustainability assessment have been outlined by Gibson et al. (2005). In the case of energy, sustainability analyses of production have been developed by Dincer & Rosen (1999), Dincer (1999) and Afgan, Carvalho & Hovanov (1999), albeit more focused on the engineering side of energy production. Sustainable energy production based on second generation biofuel (biomass) has also been considered by Bhattacharya, Salam, Pham & Ravindranath (2003) and Sudha, Somashekhar, Rao & Ravindranath (2003). Finally, Khan et al. (2007) outline and apply a sustainability assessment for energy technology at the community level.

### *2.9.1. Sustainable Community-Based Energy Technology*

The sustainability assessment described in Khan et al. (2007) considers that modern technology is based on a very limited time scale, focussed primarily on cost efficiency in the present moment. Modern technology rarely considers long-term effects on the environment, economy or society. In Khan et al.'s (2007) sustainability assessment, the primary criteria that must be met for a technology to be truly sustainable is an infinite time-scale. This means that only energy technologies that can be supported infinitely by the environment, economy and society are considered truly sustainable.

In Khan et al. (2007), various small-scale, community based renewable energy options are considered, being solar, wind, biofuel cells and biomass based energy (biodiesel, biogas and wood chips). Data collected in Mineville, Nova Scotia, Canada, asserted that community-based energy initiatives could be managed by various local groups including "NGOs, cooperatives, charities, and other non-profit organizations" (p. 409). Each type of energy technology was subjected to a mathematical time test to evaluate its long term potential. If it passed this criterion, then it was subjected to four additional mathematical criteria: environmental, ecological, economic, and social (p. 408). Khan et al. (2007) concluded that community based energy production, particularly using biodiesel and direct solar energy, are sustainable, "…considering their time-tested functionality and ecological, economic, and societal considerations" (p. 403).

### 2.10. Questions of Scale

Biofuel production in India and around the world is dominated by large-scale industrial production. Thus far, there has been little examination of small scale community based options and applications. Altenburg et al., for example, examines the production of biofuels in rural areas for economic development, but from an industrial sector point of view, i.e.: producing biofuels for domestic replacement of fossil fuels, or producing for export on the global market (2009). Similarly, Hillring (2002) focuses on the use of bioenergy in rural development in Sweden over a twenty-year period, again discussing large scale and industrial production for domestic use and sale in the EU. Karlsson & Khamarunga (2009) identify projects engaging in rural production of energy, in some cases with biofuels, but offer little analysis.

In one case, Peskett, Slater, Stevens, & Dufey (2007) discuss the positive role of biofuels in poverty reduction – through employment effects, wider growth multipliers and energy price effects. Their primary concern is that these poverty reduction effects will be lost if large-scale biofuel production is practiced. Peskett et al. (2007) conclude that "[g]lobal environmental incentives to small scale producers remain slight" (p. 6) and that there is an important need to assess the production of biofuels at the country level in order to correctly analyze patterns in global biofuel development.

In another case, Dubois (2008) argues that biofuel development must remain small-scale in order to benefit small farmers and communities. However, this investigation does not provide empirical evidence for its argument. In general, the literature indicates a need for systematic assessment of the role that biofuels can play in local community development.

## 2.11. Biofuel Summary

Potential sources for biofuel production are abundant – almost any waste (or non-waste) plant material will do. There is significant interest in the use of biofuels as a means of mitigating anthropogenic climate change, through carbon offsets and reducing global fossil fuel dependence. However, the issue is complex and requires more investigation into the possibilities and shortcomings of biofuels before one can ensure that they offer a more environmentally "friendly" energy source than fossil fuel.

# 3. Research Design and Methodology

## 3.1. Exploratory Research

For this study, exploratory research was used to investigate interrelated case studies on biofuel development and agricultural mechanization in Orissa. Exploratory research is ideal for this study as it allows for in depth investigation that can be used to understand potential scenarios and illustrate practical applications of ideas and concepts. Exploratory research is often overlooked and misunderstood as a form of social science research; however exploration is a necessary and useful tool for uncovering potential for new research (Stebbins, 2001). While exploratory research is generally not quantified, it provides detailed background information that can benefit academics, policymakers, NGOs, governments and, ultimately, individuals. Stebbins (2001) defines exploratory research as "… a broad-ranging, purposive, systematic, prearranged undertaking designed to maximize the discovery of generalizations leading to description and understanding of an area of social or psychological life" (p. 3).

## 3.2. Case Study Approach

For this research question, a representative single-case study approach was appropriate. It allowed the researcher to address a gap in the literature by examining one village level initiative aimed at integrating adaptation and mitigation approaches to climate change. The case provides an example of a process that may also prove useful in similar locations where changing climate is an issue and agriculture is prominent.

Case studies provide an opportunity to create and test research hypotheses (Yin, 2009; Flyvbjerg, 2006). The case study approach is just one of many research approaches in social sciences, but its in-depth nature lends it well to exploratory research. The case study approach can be appropriate when "(a) 'how' or 'why' research questions are being posed, (b) the investigator has little control over events, and (c) the focus is on a contemporary phenomenon within a real-life context" (Yin, 2009, p. 2). Furthermore, a case study can be used to "*enlighten* those situations in which the intervention being evaluated has no clear, single set of outcomes" (Yin, 2009, p. 20).

There are misconceptions about the efficacy of case study approaches in social sciences (Yin, 2009; Flyvbjerg, 2006). Flyvbjerg (2006) outlines his view of these misunderstandings as follows: (1) General, theoretical (context-independent) knowledge is more valuable than concrete, practical (context-dependent) knowledge; (2) One cannot generalize on the basis of an individual case; therefore, the case study cannot contribute to scientific development; (3) The case study is most useful for generating hypotheses; that is, in the first stage of a total research process, whereas other methods are more suitable for hypotheses testing and theory building; (4) The case study contains a bias toward verification, that is, a tendency to confirm the researcher's preconceived notions; (5) It is often difficult to summarize and develop general propositions and theories on the basis of specific case studies (p. 221). Flyvbjerg (2006) rebukes each of these misconceptions and instead identifies the case study approach as a relevant and useful form of research to enlighten researchers on the intricacies of a given case. A case study can allow a research to uncover facets that would be overlooked by a less detailed form of research, such as a survey.

Case studies can be carried out singly to provide a detailed and in-depth understanding of a situation in time, called single-case studies. Alternatively, case studies can be replicated many times to allow for comparative analysis, called multiple-case studies. For the purpose of this research, a single-case study was appropriate given the unique qualities of the case and research limitations, including temporal, fiscal and linguistic barriers.

Yin (2009) identifies various types of single-case studies, including the *critical* case, the *extreme* or *unique* case, the *representative* or *typical* case, the *revelatory* case and the *longitudinal* case (p. 47-50). For the purpose of this study, the representative or typical case applies. The goal of this case is to "capture the circumstances and conditions of an everyday or commonplace situation" (Yin, 2009, p. 48). It is assumed that the lessons learned can be informative of the experiences of other similar cases.

### 3.3. Research Design

The research strength lies in the various sources of data collection, including key informant interviews, government documents, NGOs and local academia, which support the case study approach.

The research was divided into three phases, illustrated in Figure 3 below. Phase one took place in Waterloo, Canada and included preparatory work for the field study and exploratory research in India. Phase two was carried out over a four month field visit to Orissa, India, and was based out of the NGO campus of Gram Vikas, which also houses the CTx GreEn office and workshop. Phase three was carried out both in India and in Waterloo, Canada and consisted of analysis of data and of dissertation preparation.

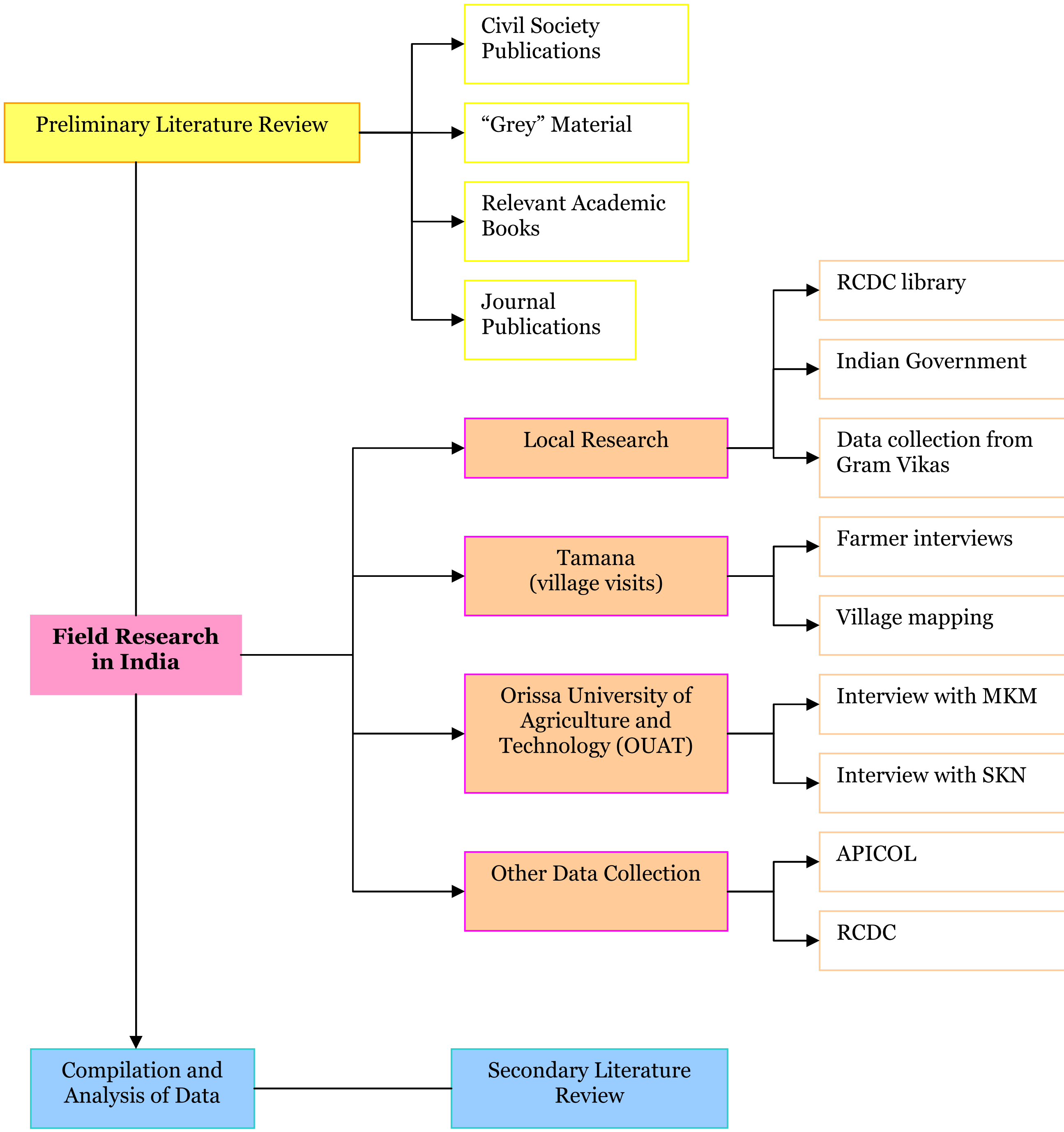



**Figure 3.** Research Design

The primary methods of data collection employed in this study were key informant interviews, participant observation and an extensive literature review. One interview was carried out with NGO representatives, two interviews with academics, two interviews with government organizations and seven interviews with farmers in the state of Orissa during the course of the field visit in India. Secondary data was collected from various NGO and university libraries in Orissa and from the Governments of India and Orissa online databases.

### 3.4. Literature Review

The literature review process for this study was extensive. Given the exploratory nature of the research, the literature was constantly updated to meet the changing requirements for the study. The review included peer-reviewed journal publications, academic literature and government documents available on online databases, in libraries and official websites.

The topics reviewed provided essential background information for research and included: biofuel development and policy in India, the production of biofuel, the role of biofuel in view of climate change, the food versus fuel debate, climate change science, the importance and shortcomings of mitigation and/or adaptation mechanisms for climate change, the Kyoto protocol and COP meetings, carbon trade certification and marketing, sustainable development, sustainability assessments, sustainable agriculture, agriculture in Orissa, agricultural mechanization in India, fluctuating weather patterns in India, farmer lifestyle and livelihoods in Orissa and India. A summary and analysis of the literature reviewed can be found in Chapter 2.

### 3.5. Key Informant Interviews

Key informant interviews were carried out during phase two of research. The fieldwork was based out of the Gram Vikas campus, located in Mohuda, Orissa, about 38km from Berhampur city and rail station and about 5km from the case study village of Tamana. Berhampur is three to five hours by train from Bhubaneshwar, the capital of Orissa, where Orissa University of Agricultural Technology (OUAT), Regional Centre for Development Cooperation (RCDC) and various provincial government offices are located.

### 3.6. Village Level Interviews

Seven village level interviews in Tamana were arranged by the researcher with the help of CTx GreEn co-founder Geeta Vaidyanathan (GV) who also acted as translator for the interviews (Oriya to English). GV volunteered as a translator after no other suitable translator was found and she was present for all village level interviews. The interviews were organized through various visits to Tamana, via a CTx GreEn intern SM who lives in Tamana village and also via cell phone. The main contact in the village to arrange interviews was RM, SM's older brother. He was chosen because of his ties with CTx GreEn, which developed through his sister and through his previous rental management of the CTx GreEn power tiller. He had also been helping CTx GreEn with research by using oilcake (a by-product of local biodiesel production) to fertilize his rice paddy fields in place of urea, the traditional local fertilizer.

Prior to embarking on the interview process, two visits to Tamana were made, first to become familiar with the design and layout of the village and to meet the Mallick family and second to meet potential interviewees. After the first village visit a map was produced by the researcher and verified by SM, reproduced in the appendix. In total, seven villagers were interviewed during three separate meetings. The first meeting was with two power tiller owners and a cycle rickshaw driver, the second with three village farmers who rent power tillers and the third with two potential entrepreneurs (one individual was interviewed on two occasions, as a power tiller renter and as a potential entrepreneur). The small group interviews were semi-structured, including a list of open-ended questions prepared in advance by the researcher and reviewed by the translator. Interviews lasted from one to two hours.

The interviews were carried out during the Rabi planting and harvesting season. During the period of the fieldwork, interviewees were alternately engaged in preparing, sowing and harvesting fields as well as transplanting winter pulses. Because it was a busy time for farmers in the village, they had little spare time for interviews, making arrangements difficult. This obstacle was compounded by several harvest related festivals that occur almost every week according to the religious calendar followed in Orissa – a state known for its numerous festivals and auspicious days. Village level interview arrangements required extensive personal contact. Many individuals do not have phone access meaning that arrangements must be made in person and it is difficult to send reminders. In the case of the first interview, the interviewer and translator arrived at the village early one morning and found that the interviewee had forgotten and was already in the field. The interview was rescheduled for the following week via SM. Other obstacles included transportation to and from the village, which was managed primarily by borrowing bicycles and renting vehicles from Gram Vikas. All of the interviews were held in the community square, a cement meeting space that is raised several feet from the road and covered with a roof. The advantage of this location was that it was large and comfortable. Its disadvantage was that often passers-by would distract interviewers and interviewees, for example a religious ceremony passing through the village or a villager requesting the advice of an interviewee.

## 3.7. NGO and Academic Interviews

### *3.7.1. CTx GreEn*

CTx GreEn played a pivotal role in the success of this study, facilitating connections with Tamana, Gram Vikas and other organizations. The founders of CTx GreEn, Ramani Sankaranarayanan (RS) and Geeta Vaidyanathan (GV) were interviewed in order to gain a better understanding of their organization and its goals in terms of biodiesel production and community development. This semi-structured interview was organized and carried out in the CTx GreEn office.

### *3.7.2. OUAT*

Two professors from OUAT were interviewed following a visit to the university with RS. The first, MKM, is a professor in the College of Agricultural Engineering and Technology and specializes in the study of production and use of biofuel from oilseeds. He was chosen in 2006 by the OFDC to manage a provincial biodiesel pilot plant in Bhubaneshwar (GoO, Orissa Forest Development Corporation (OFDC), n.d.). MKM has been producing biodiesel intermittently at the plant with the help of his students. MKM was interviewed in his office at OUAT and subsequently via phone and email for clarification. He also provided several PowerPoint presentations; photos and diagrams to illustrate his work at the integrated biodiesel plant described in section 6.2.

The second professor interviewed was SKN, from the Department of Soil Science and Agricultural Technology at OUAT. He specializes in taxonomic classification of soils and agricultural mechanization in Orissa, the latter of which was very relevant to this study. SKN was interviewed in his office at OUAT and provided information about agricultural mechanization in Orissa including its strengths and limitations and his opinion on biodiesel.

### 3.8. Government-Level Interviews

An interview with the provincial organization APICOL was arranged during a visit to Bhubaneshwar. The interview was arranged via a connection from CTx GreEn with Mr. Bhanja from VST tractors, a tractor company that works with APICOL regularly. The purpose of this interview with Mr. Subhokanta Bhuyan and Mr. Manmohan Senapati was to understand the role and extent of government subsidies offered to farmers to increase agricultural mechanization in Orissa.

### 3.9. Participant Observation

Participant observation played a key role throughout the field research phase, particularly during visits to Tamana and during the stays with CTx GreEn and OUAT. Many observations were clarified or discussed during interviews and these observations were important for preparing interview questions. Researcher observations were recorded in a journal and were used during data analysis as appropriate.

### 3.10. Data Analysis

Preparation for analysis began by compiling detailed notes taken during interviews with farmers in Tamana. Notes were then fleshed out into summaries, which were cross-checked with GV (translator) for accuracy. The summaries were scanned for themes relating to farming practices, crop production, crop sale and use of farm machinery.

Next, notes from interviews with NGOs and academics were compiled and fleshed out into summaries. Themes involving farming practices, machinery use in agriculture, biodiesel production, biodiesel consumption, biodiesel by-product uses and community involvement in biodiesel production were revealed. Finally, concepts and ideas revealed in the literature review were cross-checked using themes revealed from the interview analyses, providing context for the case study approach.

### 3.11. Limitations

The methodology was limited to examination of one case study village in India, removing the possibility of comparative research. There were other villages in the area of this study but language barriers and time constraints limited the research scope. Research was tied to partner NGOs Gram Vikas and CTxGreEn, which provided support via a translator, transportation and connections with villagers and farmers. Convenience-sampling was used—dictated by when both farmers and a translator were available at the same time. Status as an outsider made it difficult to arrange interviews without the participation of a member of CTx GreEn, further dictating the number of interviews conducted and their locations. Interviews were not recorded due to concerns about cultural sensitivity. Instead, data was extracted from interview notes rather than transcriptions. Finally, the necessity of having a translator opened possibilities for response bias among interviewees due to the translator being a friend or colleague.

### 3.12. Ethical Considerations

This study was reviewed by and received ethics clearance through the Office of Research Ethics at the University of Waterloo. Written or verbal consent (in cases of illiterate participants) was obtained from all participants.

Interviews were voluntary and were established based on connections with villagers through affiliates of CTx GreEn. The first language of villagers in Tamana is Kui. However, all interviewees spoke Oriya, the state language of Orissa. With the aid of a translator, all village level interviews were carried out in Oriya. There is potential for misunderstanding and loss of meaning in translation, both from Kui to Oriya and from Oriya to English.

# 4. Case Study Context

## 4.1. Introduction

Agriculture is very important in India. Over 58 percent of the working population depends on agriculture for a livelihood, compared to only 2.8 percent of the working population in Canada (Puttaswamaiah, Manns, & Shah, 2005). Agricultural practices in India have been honed over centuries, but underwent a large shift during the green revolution in the late 1960s and 1970s (Shiva, 1991). Practices moved from small family-laboured farms with little technology and inputs to larger scale, mechanized agriculture with heavy fertilizer and pesticide use (Puttaswamaiah et al., 2005; Shiva, 1991). The type of seeds employed changed as well, with a shift from seed-saving and seed banks to purchasing High Yielding Varieties (HYV) from multinational agribusiness promoted by the green revolution (Shiva, 1991).

In 2008-2009, the all-India average for fertilizer use (N, P & K) per hectare was 128.58 kg/ha, up from 111.76 kg/ha in 2006-2007. The average fertilizer use in Orissa was 61.64 kg/ha in 2008-2009 (GoI, MoA, 2009). The all-India consumption of fertiliser in 1950-51 was approximately 65,600 tonnes, prior to the introduction of green revolution practices. This increased dramatically to 2,177,000 in 1970-71, to 11,040,000 in 1988-89, and finally up to 24,909,300 in 2008-2009 (GoI, MoA, 2009). This represents an increase of 390 times the inputs in less than 60 years.

The green revolution itself is a subject of controversy because in the medium run it contributed to an increase in food production and availability. However, it also had significant social impacts, including reversing years of land reform by the Indian government aiming to put land in the hands of the landless. Instead, the green revolution led to a consolidation of land holdings and land moved in the opposite direction—from the poor to the rich (Shiva, 1991). HYV seeds introduced were more vulnerable to pests, which the green revolution approached with higher pesticide input. The limited genetic base of HYV seeds and their quick dispersion across the country led to a loss of seed and plant diversity. Finally, incentives under the green revolution to increase irrigation (for production of non rain fed crops) led to severe water shortages and soil erosion (Shiva, 1999).

The production of major food crops in India increased in the 1970s. However, "the overall growth rate of crop production declined from 3.19 percent per annum during 1980s (1980-81 to 1989-90) to 2.28 percent per annum during 1990s (1990-91 to 1999-00), while yield growth decreased from 2.56 percent per annum to 1.31 percent per annum" (Puttaswamaiah et al., 2005, p. 15). Several issues in newly industrialized Indian agriculture have led to a decrease in productivity. These issues include land degradation, water shortages and modern technology (expensive inputs, imbalanced nutrient systems in the soil due to fertilizer dependence, increased vulnerability to pests due to high pesticide use) (Shiva, 1991; Puttaswamaiah et al., 2005). These concerns highlight a need for more sustainable agricultural practices.

India has various options to implement a more sustainable agricultural system. Some mechanisms that will allow India to lower GHG emissions and create carbon sinks are outlined by Pretty, Ball, Xiaoyun, & Ravindranath (2002). They include but are not limited to: adopting soil conservation measures; applying composts to increase soil-organic matter stocks; cultivating perennial grasses instead of annuals; converting marginal agricultural land to woodland to increase carbon base; substituting biofuel for fossil-fuel consumption; zero-tillage to reduce CO2 emissions from soil; reducing use of inorganic nitrogen fertilizers and adopt targeted, slow release fertilizers; use of integrated pest management instead of pesticides; use of biogas digesters to produce methane to substitute fossil fuel use, and; use of improved cookstoves to increase efficiency of biomass fuels. Implementing any and all of these mechanisms in a sustainable agriculture plan could allow farmers to increase productivity while lowering costs and reducing environmental impacts (Pretty et al., 2002).

#### *4.1.1. Sustainable Agriculture in India*

In 2000, the Government of India's Ministry of Agriculture released a National Agriculture Policy (NAP), outlining steps for sustainable agriculture and organic farming. The policy seeks "…to promote technically sound, economically viable, environmentally non-degrading, and socially acceptable use of country's natural resources – land, water and genetic endowment to promote sustainable development of agriculture" (GoI, MoA, 2000). However, the Government of India remains in a conundrum where it must increase agricultural production to provide food for domestic consumption and foreign exchange, while minimizing environmental impact where possible.

The Government of India has also recognized that organic agriculture may provide a unique export niche, particularly for commodities in which India already holds a comparative advantage. These include cash crops such as sugar, cotton, tea and coffee (Puttaswamaiah et al., 2005). The Central Government has implemented a set of standards for export of organic products under the National Programme for Organic Production (NPOP) (Willer, Yussefi-Menzler, & Sorenson, 2008). Between 2005 and 2006, India had the second highest increase in organic agricultural land from a survey of 90 countries. India had an increase of more than 300,000 ha, and the total area under organic agriculture in the country is now over 500,000 ha (Willer et al., 2008).

#### *4.1.2. Appropriate Technology*

The Gandhian principal of appropriate technology is especially applicable in the context of sustainable agriculture and sustainable development in India. Gandhi maintained that "India needs production by the masses and not mass production," heavily promoting the development of rural technologies to strengthen community self-reliance (Bakker, 1990). Development of small scale industries through rural entrepreneurship can lead to individual and community development, as well as job creation (Kumar, 2010).

### 4.2. Agricultural Mechanization in India

India's total geographical area is 329 million hectares. The net sown area of food grains in the country in 2007-2008 was 124.07 million hectares, accounting for almost 40 percent of total area (GoI, MoA, 2009). The total geographical area of Orissa is 15.6 million hectares. The net sown area of food grains is 5.49 million hectares, or about 35 percent of total state area (GoI, MoA, 2009). These numbers apply only to food grain production, including rice, wheat, jowar, bazra, maize, gram and tur. They do not include oilseeds such as groundnut, soybean, sunflower and rapeseed or cash crops such as cotton, sugarcane, jute, onion and potato (GoI, MoA, 2009). Agriculture is a major livelihood support both in India and Orissa and it plays a very important role in the economies of both state and country. During 2004-2005, the last year in which comparable data is available, agriculture represented 17.4% of national GDP at current prices and 21.4% of state GDP at current prices (Estimated from data in GoI, MoA, 2009, p. 52 and GoO, DAFP, 2008, p. 78).

The average land holding in India is 1.57ha (GoI, MoA, 2009). These holdings are often subdivided into smaller parcels due to Indian family law, which dictates that each son receives an equal share of his father's land. Holdings are characterized by small fragmented land, hill farming, shifting cultivation and areas of cultivable water logged land, all of which make land holdings more suitable to animate power including humans and bullocks, rather than mechanization (Alam & Singh, 2003). In 2000-01, 62.3 percent of landholdings in India were marginal (less than 1 hectare) (GoI, MoA, 2009). Small (1-2 ha) landholdings made up 19 percent, 11.8 percent semi-medium (2-4 ha), 5.5 percent medium (4-10 ha) and 1 percent large (10 ha and above) (GoI, MoA, 2009).

When HYV crops were introduced during the green revolution, higher energy inputs and efficient management practices were enforced under the scheme. In order to meet "…desired cropping intensity with timeliness in field operations, animate energy sources were no longer adequate" (Alam & Singh, 2003, p. 6). The green revolution actively encouraged farmers to supplement animate power with mechanization. According to research by Singh (2006), animate power in Indian agriculture has decreased significantly from 1606 MJ/ha in 1970-1971 to 907 MJ/ha in 2000-2001. Total mechanical energy on Indian farms has increased from 345 MJ/ha in 1970-71 to 8270 MJ/ha in 2000-2001 (Singh, 2006). This shift cannot be solely attributed to the green revolution. During the 1960s and 1970s, machinery from abroad became widely available in India (Shiva, 1991). In this same era, structural adjustment programs were introduced by the World Bank and the International Monetary Fund to "lift" the third world out of poverty. These schemes promoted the role of domestic incentive measures to increase agricultural production, which thereby followed a similar ideology to the green revolution (Belassa, 1982).

The all-India livestock census in 2003 found a decline in work animals over 1997 levels, which includes cattle and buffalo. Working cattle population decreased by 4.3 percent and buffalo population decreased by 14.2 percent, indicating a significant shift in draught animal population (GoI, MoA, DAHD, 2005). The decline in draught animals has accompanied a relative increase in mechanization in India.

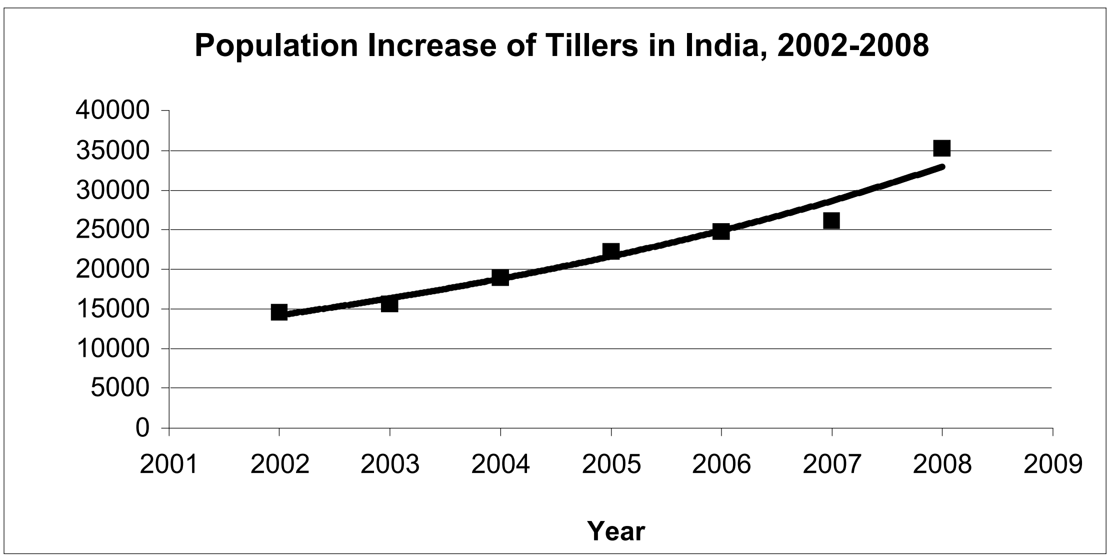
There are many mechanized tools used in Indian agriculture. The bulk of these are employed as attachments with a tractor or a power tiller. For this reason, tractors and power tillers are used in this study to examine mechanization in rural small scale agriculture. Mechanization for the purpose of this study means any use of machinery to assist in farming practices, differentiated from human or animal power. A tractor is a four-wheel ride-on machine, which allows farmers to plough, sow and harvest a field. In many cases it is also used as a vehicle for general use or hauling harvest. A power tiller is essentially a two-wheel tractor, which allows for more economical, flexible and compact use while still achieving faster results than draught animals. Tillers are not as functional as a vehicle for long distance hauling when compared to a tractor, although they can be used as a ride-on vehicle over short distances.

It is difficult to quantify the number of tractors and tillers currently in use in India today, however, an average of three estimates shown in Table 1 approximate the populations at 274,506 tillers and 4,759,844 tractors in India in 2000. Data from three Government of India sources suggest that power tiller use has grown in India steadily since 2002, illustrated in Figure 4. These figures only represent purchases of new machinery and so do not account for any informal refurbishing, trading or upgrading of older models. Another estimate from The Energy and Resources Institute (TERI) in New Delhi shows that sales of tractors and tillers increased considerably between 1982 and 2008, from 63 thousand tractors and 2 thousand tillers in 1982-83 to 200 thousand tractors and 18 thousand tillers in 2007-2008 (TERI, 2009).

| | Singh, Gyanendra (2006) | | Srivastava S.L. (2006) | | Nanda, S.K. (2009) | |
|---|---|---|---|---|---|---|
| **Year** | **Tillers** | **Tractors** | **Tillers** | **Tractors** | **Tillers** | **Tractors** |
| **2000-2001** | 122000 | 2599 | - | - | - | - |
| **2001-2002** | 135563 | 2824280 | 93884 | 2759936 | - | - |
| **2002-2003** | 150176 | 2997378 | 108497 | 2933034 | - | - |
| **2003-2004** | 165841 | 3187714 | 124162 | 3123370 | - | - |
| **2004-2005** | 183322 | 3435245 | 143147 | 3371063 | - | - |
| **2005-2006** | 205625 | 3731325 | 165450 | 3663971 | - | - |
| **2006-2007** | 230416 | 4084106 | 190241 | 4016752 | - | - |
| **2007-2008** | 256551 | 4430607 | 216376 | 4363253 | - | - |
| **2008-2009** | 291847 | 4773443 | 251672 | 4706089 | 280000 | 4800000 |

(Singh, 2006; Srivastava, 2006; SKN, personal communication, 2009)

**Table 1.** Tiller and Tractor Numbers in India: Comparative Data Analysis (No.)




(Srivastava, 2006, p. 4.; Singh, 2006; GoI, MoA, DoAC, 2009, p. 77)

**Figure 4.** Population increase of Tillers in India, 2002-2008.

| Year | Agricultural land (%) | Surface Area ($km^2$) | Ag. Land ($km^2$) | Tractors per sq. km of arable land | Tractors in India (est.) |
|---|---|---|---|---|---|
| 2000 | 60.8 | 3287300 | 1998678 | 141 | 281813654 |
| 2005 | 60.6 | 3287300 | 1992104 | - | 280886636 |

(Source: World Development Indicators Database, 2009)

**Table 2.** Estimated number of tractors in India.

Data from the World Development Indicators Database (WDI) (2009) can be used to provide an estimate of the total tractors in India in 2005. Total land surface in India according to WDI was 3,287,300 $km^2$ in 2005. Approximately 60.6 percent of this was deemed as "agricultural land" in the same year (down from 60.8% in 2000). This translates to approximately 1,992,104 $km^2$ of agricultural land available in 2005. Using the figure of 141 tractors per sq km of arable land in India in 2003, we can estimate that there were approximately 280,886,636 tractors in India in 2005. This figure should be understood as the best estimate possible with the data available, but one which should be accepted with considerable caution, since the data years available do not match up. The figure derived from the WDI is much larger than the figures quoted by G. Singh (2000) and Srivastava (2000) in Table 1, which average approximately 3.4 million in 2005 and around 4.7 million in 2009. Estimates by G. Singh (2000) and Srivastava are more comparable to an estimate made by personal communication with SKN in November 2009 which was 4,800,000.

A pair of cattle is about 10 times more powerful than an adult man, a power tiller is 10 times more powerful than a pair of draught animals, and a tractor is 2.5 times more powerful than a power tiller (25 times a pair of draught animals) making it the most powerful agricultural tool available [see appendix for a comparison of agricultural tools]. However, due to size and cost, the tractor still remains an inefficient tool for the majority of India's farmers who have small land holdings and low cash flow. Still, the tractor population in India is more than 100 times the tiller population which can be explained by the fact that the tractor is most attractive to large farmers who own large tracts of land. Alam & Singh (2003) recognize that the growth of tractor population in India has not been uniform but has been highest in a handful of states, including Uttar Pradesh, Punjab, Madhya Pradesh, Haryana, Rajasthan, Gujarat and Maharashtra. In these states the intensity of tractor population is very high, for example in Punjab where there are only 14 ha/tractor, or Haryana, which has 18 ha/tractor.

Approximately 9.3 million farm holdings in India are identified as medium (4-10 ha) or Large (>10 ha) representing 73.94 million hectares of India's 165.6 million hectares of land holdings. Given our estimation of approximately 5 million tractors in India, there is a strong likelihood that many of the tractors belong to owners among the group of 9.3 million medium and large landholdings (Alam & Singh, 2003, p. 7; Singh, 2006; Srivastava, 2006). In contrast, there are only about 274,000 power tillers in India – an agricultural tool that is not powerful enough for a medium or large land holder but is much more attractive to the 96 million semi-medium (2-4 ha), small (1-2 ha) and marginal (<1 ha) land holders, the bulk of which are not in a financial position to easily invest in machinery (Alam & Singh, 2003, p. 7; Singh, 2006; Srivastava, 2006). In financial terms then it is possible to speculate that large farmers invest first in a tractor over a power tiller but that the tiller population would still be on the rise as smaller farmers invest in machinery either as income increases or machinery-for-hire becomes more available.

Custom hiring of tractors is becoming more popular for tillage, transport and threshing (TERI, 2009). This is as a result of a Government of India scheme to promote Agro Service Centres in rural areas, which is also responsible for the various subsidies available for purchasing machinery (Sharma, Singh & Panesar, 2006).

### 4.3. Subsidies for Agricultural Machinery

Government subsidies for farm machinery are available under two schemes funded by the Governments of India and Orissa, but managed by the state of Orissa: Rashtriyi Krishi Vikas Yojana (RKVY) and the Work Plan on Macromanagement of Agriculture (herein referred to as Work Plan). RKVY is a 100 percent Central Government funded scheme that is delegated to the state, provided that the state meet specific guidelines, including maintaining a high level of state-wide agricultural spending. The Work Plan is the Government of Orissa's agricultural incentive plan, which coordinates the spending of money from participation in various GoI incentive plans, such as the RKVY. The Work Plan is 90 percent funded by the GoI. The remaining 10 percent is funded by the GoO. Therefore, subsidies for agricultural machinery fall under both the RKVY and the Work Plan.

The Government of Orissa nodal agency to manage RKVY and the Work Plan is the Agricultural Promotion and Investment Corporation of Orissa, Ltd. (APICOL). It is located in the state capital of Bhubaneshwar. The agency manages the funds under each scheme and works with several machinery distributors in all the districts of the state. RKVY funds a variety of activities to increase agricultural productivity, including mechanization, fishery development, HYV seeds, soil quality development and integrated pest management, among others. However, tractors are not covered under RKVY and instead fall under the Work Plan. RKVY instead suggests that "Assistance would be provided for farm mechanization efforts especially for improved and gender friendly tools, implements and machinery," which includes power tillers (GoI, MoA, n.d.). The Work Plan covers power tillers, tractors, paddy reapers, paddy transplanters, power operated implements, bullock drawn implements and various other implements. Machinery brands are limited under the schemes but for power tillers they include: KAMCO, VST, Mano Kabota, Shrachi, Gorga Seifong, Sociza Seifong, and Greaves. Power tillers must be between 9 and 13 HP to qualify. Tractor brands include: Eicher, Swaraj, TAFE and Mahindra and must be under 30 HP (GoO, DAg, 2006; GoI, MoA, n.d.).

Table 3 presents the year wise achievement of APICOL under the Work Plan and RKVY from April 1, 2002 to March 31, 2010 (with provisional numbers for 2009-2010). The data suggests that more power tillers have been purchased using the subsidy schemes than tractors, which is expected given that tractors are only eligible under one scheme. Data also indicates that it is likely many tillers and tractors are purchased without subsidies, perhaps due to brand or HP or other elements that render the purchaser ineligible under the schemes.

| | **Power Tiller** | | **Tractor** | | **Both** | |
|---|---|---|---|---|---|---|
| | **Total Nos.** | **Total Amount (Rs.)** | **Total Nos.** | **Total Amount (Rs.)** | **Total Nos.** | **Total Amount (Rs.)** |
| **2002-2003** | 663 | 17,478,541 | 144 | 4,320,000 | 807 | 21,798,541 |
| **2003-2004** | 1540 | 41,153,531 | 595 | 17,850,000 | 2135 | 59,003,531 |
| **2004-2005** | 2105 | 57,362,729 | 740 | 22,200,000 | 2845 | 79,562,729 |
| **2005-2006** | 2703 | 73,944,228 | 1123 | 33,690,000 | 3826 | 107,634,228 |
| **2006-2007** | 2976 | 81,173,051 | 1366 | 40,980,000 | 4342 | 122,153,051 |
| **2007-2008** | 3342 | 100,357,914 | 712 | 25,605,000 | 4054 | 125,962,914 |
| **2008-2009** | 7182 | 400,989,258 | 1679 | 142,907,500 | 8861 | 543,876,758 |
| **2009-2010*** | 221 | 13,103,800 | - | - | 221 | 13,103,800 |
| **Grand Total** | - | - | - | - | 27091 | 1,073,095,552 |

(M. Senapati, personal communication, 2009)
*Note: Years is from 01-04 to 31-03*
** indicates provisional*

**Table 3.** Year Wise Achievement under Work Plan and Rashtriyi Krishi Vikas Yojana

The Work Plan covers 25 percent of the cost of power tillers, up to Rs. 27, 500 and 25 percent of the cost of tractors up to Rs. 30, 000, which results in significant savings for the farmer. In an interview with BM, a tiller owner in Tamana, he revealed that he paid Rs. 73,000 initially and was returned Rs. 15,000 after the dealer claimed subsidies on his behalf (about 20 percent return). He mentioned that there may be corruption on the part of the dealer and if one is not careful the dealer may not return the full subsidy amount to the purchaser.

Along with the mechanization subsidies, both RKVY and the Work Plan offer farmer demonstrations, training sessions, soil testing, seed distribution and technology transfer. Farmers may be able to attend courses or workshops subsidized under the schemes and offered through the state nodal agency or state government ministries and departments (GoO, DAg, 2006).

### 4.4. Diesel Consumption in Agriculture

High speed diesel fuel is an important fuel used in agriculture for tractors, tillers and irrigation pumps. The total diesel consumption in India increased steadily at a rate of 7.28 percent each year between 1980 and 2000. Of that, diesel consumption for agriculture accounted for about 9 to 10 percent of the total consumption since 1980 (Alam & Singh, 2003). Trends in energy use in agriculture suggest that human and animal energy use is decreasing while mechanical energy (including tractors, tillers, diesel pumps and electric motors) are increasing (TERI, 2009; Alam & Singh, 2003). The trends in energy use from 1971 to 2006 can be seen in Table 4.

| **Share of total power in the agricultural sector in India (in percentage)** | | | | | | | |
|---|---|---|---|---|---|---|---|
| ***Year*** | ***Agricultural Worker*** | ***Draught Animal*** | ***Tractor*** | ***Power Tiller*** | ***Diesel Engine*** | ***Electric Motor*** | ***Total Power (kW/ha)*** |
| **1971-72** | 15.11 | 45.26 | 7.49 | 0.26 | 18.11 | 13.77 | 0.295 |
| **1981-82** | 10.92 | 27.23 | 19.95 | 0.33 | 23.79 | 17.78 | 0.471 |
| **1991-92** | 8.62 | 16.55 | 30.21 | 0.4 | 23.32 | 20.9 | 0.759 |
| **2001-02** | 6.49 | 9.89 | 41.96 | 0.54 | 19.86 | 21.26 | 1.231 |
| **2005-06** | 5.77 | 8.02 | 46.7 | 0.6 | 18.17 | 20.73 | 1.502 |

(TERI, 2009, p. 268)

**Table 4**. Share of total power in the agricultural sector in India (in percentage).

## 4.5. Agricultural Mechanization in Orissa

When compared with other predominantly agricultural states in India, Orissa has a lower rate of mechanization due to three factors: small average landholdings, family farming for subsistence rather than cash cropping, and low cash flow. In the year 2000-2001, the Government of India estimates that Orissa had 2,295,000 marginal landholdings (<2.5 acres or <1 ha), making up 56.4 percent of total landholdings in the state. This is compared to 1,114,000 small, 501,000 semi-medium, 145,000 medium and 13,000 large. Total Orissan landholdings in 2000-2001 amounted to 4,067,000 (GoI, MoA, 2009). It is clear that marginal landholdings make up the bulk of Orissan agriculture, with an average size of 0.5 hectares. Meanwhile, large landholdings make up only 3.2 percent of total holdings, with an average size of 16.48 hectares (GoI, MoA, 2009).

Orissa is considered a medium draught power intensity state based on 1992 data, which indicated that there were 2.22 acres of land per draught animal pair. This is compared to a low draught animal intensity state such as Punjab where there is a high level of mechanization, which has 10.66 acres of land per pair of draught animals (Alam & Singh, 2003). In Punjab in 2003 there were 71.88 tractors per 1000 ha; while in Orissa there were 1.29 tractors per 1000 ha. The all-India average was 12.85, or almost 12 times Orissa's tractor intensity (Alam & Singh, 2003).

The Central Institute of Agricultural Engineering in Bhopal, India, conducted a major survey of energy demand and energy use patterns in various states across the country for several crops between the years 1971-1983 (first phase) and 1983-1997 (second phase). Orissan rain fed paddy and rain fed groundnut was included in the study and it was recorded that during the first phase of the study no tractive power was being used for paddy in Orissa. This increased to 9.3 h/ha in the second phase. Alternatively, animal power decreased by 6.4 percent between survey periods (De, 2005). For groundnut production in Orissa which happens after the harvest of paddy, resource rich Orissan farmers began using tractive power during the second phase for "initial opening of the field and final field preparation but resource poor farms used tractor for initial opening of field and final field preparation with bullock plough" (De, 2005, p. 102). Again for groundnut cultivation the "use of animal power decreased by 17.8 percent whereas tractor power increased from zero to 5.4 h/ha" (De, 2005, p. 103). De (2005) notes that the most cited reason for declining draught animal power is the increasing cost of maintenance. Farms that used mixed energy sources (animal and tractive) generally hire tractors and tillers when required whereas resource rich farms generally own a tractor and do not rely on draught animals. Increased tractive power began in the mid-1980s and continues currently. De (2005) concludes, "with favourable field size and availability of matching implements, higher powered tractor uses have exhibited better operational energy use efficiency [and d]iesel energy consumption per hectare has reduced in such cases" (p. 104). However, even in higher mechanized states such as the Punjab, annual tractor use has not exceeded 338 hours, meaning that it is not economically viable to use a tractor only for agricultural purposes (De, 2005). According to Alam & Singh (2003), the desired level of annual use for tractors is around 1000 hours, in order to maximise investment. Therefore, tractors must be used additionally for transport and hauling to be cost efficient (De, 2005).

## 4.6. Scheduled Tribes and Castes

Orissa was home to one of the most powerful ancient Indian kingdoms of Kalinga, which predates Brahminical influence. Tribal cultures and traditions dominated in the area of Orissa and parts of Andhra Pradesh up until the 16$^{th}$ century CE, when the area was conquered by the Mughals and the caste system was introduced (GoO, DIT, n.d.). Orissa has strong Scheduled Tribe (ST) and Scheduled Caste (SC) populations, groups that despite their designation have often been marginalized by society. The total population of Orissa was approximately 36.7 million in 2001, of which 8.1 million were ST (22.13 percent) and 6 million were SC (16.53 percent). In Ganjam district (where the case study village of Tamana is located), there are approximately 91,000 individuals registered as ST, which constitutes about 2.88 percent of Ganjam's total population of 3.2 million. Ganjam also houses approximately 590 million SCs, which is about 18.57 percent of its population (GoI, MoHa, 2001). From a nationwide perspective, the 2001 Census of India indicated that of the total population of 1.02 billion, 8 percent of Indians are ST and 16 percent are SC.

There are 645 legally recognized Indian tribes and "backward" castes designated in the Fifth Schedule of the Constitution of India as "Scheduled Tribes and Castes". India's tribal groups are also commonly referred to as *Adivasi*, a term which encompasses all of the various tribes across the country (Human Rights India, n.d.). SCs are commonly called "Dalits" and were known as the "depressed classes" under British Indian rule (Human Rights India, n.d.). Members of STs and SCs in India are legally guaranteed "equal opportunities" in government, education and employment.

# 5. Case Study of Tamana

## 5.1. Village Profile

Tamana is a small hamlet of 85 households (estimated as of 2009) located just 5km from the Gram Vikas main offices in Mohuda and 38km from the closest major city, Berhampur. It belongs to the Sihala Gram Panchayat and is located inland in the Ganjam district of Orissa.

All the individuals in Tamana's 85 households belong to a Scheduled Tribe (ST). In the last decade, new settlers have arrived in the area of Tamana. One settlement in particular is made up of Oriya speakers and is known as "Oriya *basti*". "*Basti"* is the Hindi or Urdu term for "settlement". Oriya is the official language of the state of Orissa but it is generally a second language to tribals. By calling the new addition to Tamana "Oriya *basti*", there is an indication that those who have settled there are unlikely to be members of a ST. The settlers of Oriya *basti* are not included in the 85 household count and their numbers are unknown at this time.

The first language spoken among tribals in Tamana is *Kui*, a Dravidian language without its own written script that has been passed on through many generations. It is the language most famously spoken by the *Dongria Khonds* of Orissa who have recently come up against Vedanta, a British mining company looking to expand business in the landholdings of the Adivasis (Amnesty International, 2009).

There are 67 households in Tamana living below the poverty line, which amounts to 79% of the population of the hamlet. The Government of India defines both an urban and a rural poverty line by state. Based on the year 2004-05, the rural poverty line in Orissa was Rs. 325.79 per capita, per month[4] (based on a uniform recall period (URP)) (GoI, PC, 2007). For the same year, the Government reported that over 46% of rural Orissans were below the poverty line, which is far lower than the 79% in Tamana, indicating that Tamana has a relatively high percentage of population living below the poverty line compared to other areas of rural Orissa. The total population of the hamlet in 2009 was 385, constituting 198 males and 187 females. Primary

[4] Rs. 325.79 is approximately $7.34 CAD (conversion calculated using exchange rate on April 6, 2010 at 44.39 rupees to $1 CAD.

occupations in the hamlet include but are not limited to, agriculture, wage labour, artisan and service. At the time of the last Gram Vikas census in 2000, there were 18 landless households, 37 with marginal (<2.5 acres) holdings, 25 with small (2.5-5 acres) holdings, 4 medium farmers (5-12 acres) and no large farmers (> 12 acres).

Tamana began its affiliation with Gram Vikas (GV) early on because of its proximity to the main office location. In 1992, GV launched the Rural Health and Environment Programme (RHEP) which was focused on improving heath and sanitation because "[i]n rural Orissa less than 20 per cent have access to protected water, […] less than 1 per cent to piped water supply […] less than 5 per cent have access to sanitation" (Gram Vikas, 2004, p. 1). The RHEP was initiated in Tamana in 1995 and in just under 15 years a corpus fund of Rs. 93,000 has been generated. The village corpus fund is placed in a fixed deposit, "the interest from which is used to extend water supply and sanitation facilities to new families in the village in the future" (Gram Vikas, 2005, p. 4).

Since the initiation of the RHEP, 85 toilets and bathing rooms have been constructed, one for each household. A main tenet of RHEP requires that individual households take responsibility for their toilets and bathing rooms to ensure that they are used and maintained long after the NGO pulls out of the project. A gravity flow water system was recently installed in Tamana. There is a large cement water tank on the hill overlooking the hamlet. The end result is that there is piped water supply to toilets, bathrooms and kitchens of all families. The external investment in the RHEP was Rs. 718,000 in order to provide the infrastructure for basic health and sanitation. The people's contribution has been Rs. 114,000, primarily in the form of unskilled labour, stones, etc.

The clay houses in Tamana were constructed as part of the Gram Vikas Housing Programme in the 1990s. All of the 85 houses in the hamlet are permanent houses. The houses were built in rows "to allow for resource and space efficiency" (Gram Vikas, 2005, p. 4) in a fashion that is meant to support tribal customs and also provide protection against natural disaster. This is particularly important because the state of Orissa is highly prone to cyclones and hurricanes. The cost per housing unit built in Tamana was Rs. 22,500 and the entirety of this cost was covered by grants and loans. The Council for Advancement of People's Action and Rural Technology (CAPART) contributed Rs. 14, 500, Gram Vikas contributed Rs. 5,000 and the remaining Rs. 3,000 was taken in the form of a loan from Vysya Bank. The people in the hamlet contributed local materials for building and unskilled labour during the construction phase. As of 2009, 90 percent of the housing loans have been recovered.

Tamana has a pond and engages in pisciculture, which brings in between Rs. 25,000 and 30,000 per year, recently. Many families and households receive ongoing support from Gram Vikas in the form of livelihood development. For example, 14 families receive support for agriculture, 30 families are engaged in skill development and 35 families receive support for businesses.

There is an elementary school in the community but students must travel to a nearby hamlet or to Berhampur to attend high school. Literacy rates in the village are highest among males aged 6 to 14, at 75.15 percent, compared to 47.97 for females of the same age group, estimated in 2001. In the age range of 14-18 the gender divide is almost invisible, with 65.74 percent of literate males and 64.26 percent of literate females. However, the divide is very apparent again in the age range of 18-35, with 54.88 percent of literate males versus 17.76 percent of literate females. Above the age of 35 literacy rates drop significantly for both males and females, the former to 16.71 percent and the latter to a mere 1.41 percent.

### 5.2. Agriculture in Tamana

The major crop grown in Tamana is rice paddy, for family subsistence. The farmers in Tamana plant one yearly harvest of rain fed rice after the monsoon since it is expensive to pump water in the dry season. Pump rental must be paid for in advance, which is difficult due to low cash flow. Planting a second rice harvest during the dry season became the norm across much of India after the green revolution introduced high yield varieties of rice and new irrigation methods. However, this practice has yet to extend to Tamana or much of Ganjam district in Orissa.

The paddy crop in Tamana is planted just after the rainy season to take advantage of natural flooding and it is harvested in December/January, depending on the particular weather patterns.

When the rice is harvested, vegetables, pulses and oilseeds are planted and these are harvested through the dry season, until May. Other crops grown in Tamana for family consumption or sale include tomatoes, several types of beans, pumpkins, squash, finger millet (also known as *ragi* or *mandia* in Oriya), bitter gourd (also known as *karela* or *kalara* in Oriya), and oilseeds such as groundnut, mustard and castor. The cash crop of choice in Tamana is tomatoes since they fetch a good price on the market and are relatively fast growing. These tomatoes can be sold at markets nearby and farmers must take the bus from Tamana to sell their vegetables. In 2010, interviewee AP was able to sell 682 kg of tomatoes at a market in Rhonda for Rs. 5000 approximately. He was able to make a small profit.

The per capita rice consumption in India is approximately 76.8 kg, which could amount to over 700 kg for a family of 10 (Wailes & Chaves, 2009). Generally families are unable to grow all the rice they need for the year and must supplement their rice stores with rice purchased from the government at a subsidized price. According to Tamana farmer CM, if 75 kg of paddy are harvested, about 50-60 kg will be of edible rice and about 10-15 kg will be husk. The husk is fed to bullocks to increase their energy intake and is often saved for days when the bullocks are used for particularly hard labour. Once the rice is harvested and de-husked, it is stored in pits dug out in front of houses in the village both to maintain freshness and because of the size of the rice stores [Figure 5].

**Figure 5.** Photo of dug out rice stores in Tamana, January 2010 (Photo by Nava Dabby).

Land holdings in Tamana are marginally sized (<2.5 acres or <1 ha) and most farmers are family farmers, meaning that land has been passed down through generations of males. There are many circumstances in which land must be sold to pay bills and slowly land is consolidating in the hands of larger landowners. The amount of land owned by an individual or family is a sign of class. In the case of Tamana, one of the major landholders is also the president of the village, Banomali Mallick (BM), who owns approximately 40 *bhorono*[5] of land (~ 8 acres or 3.24 hectares). The larger landholders tend to have more available income for the purchase of machinery and tools to make agriculture more efficient. BM was able to purchase a power tiller outright from the dealer using government subsidies but without taking a loan from the bank. For smaller landowners with less cash income a loan would be required to purchase machinery, which is a large deterrent, despite the subsidies offered by the governments of Orissa and India [section 4.3].

The fields are generally managed by members of the same family but during harvest time it is necessary for farmers to hire more field hands. Labourers are paid differently based on where they live (how far away) and their gender. Typically women are paid less under the assumption that they are less efficient workers than men. De (2005) estimates that an adult woman is equivalent to approximately 0.8 of an adult man (see appendix). Children are considered to be half as efficient as an adult male (De, 2005). Labourers are also paid significantly less in rural areas and there is no enforced minimum wage. In Tamana labour costs amount to about Rs. 30 to 50 per person per day for an approximate total of Rs. 5000 per harvest. The labourers are recruited from surrounding areas and are provided with lunch by the farmer. Table 5 indicates the approximate cost of labour required to harvest 1 acre of paddy in Tamana, as estimated by RM and CM.

[5] 1 acre is equal to approximately 5 bhorono or 30 nauti. 1 hectare is equal to 2.47 acres, so 1 hectare is equal to approximately 12.35 bhorono or 74.1 nauti.

| ACTIVITY | # OF PEOPLE | COST (RS.) |
|---|---|---|
| Sowing | 20 | [50-60/person] |
| Weeding | 15 | [50-60/person] |
| Cutting | 15-20 | [50-60/person] |
| *Bantili* (tying) | -- | 300 |
| *Banktimiti* (stacking) | -- | 200 |
| Loading | -- | 600 |
| *Kohili* (unloading) | -- | 200 |
| *Sagada* (transportation via rented bullock) | 1 | 300 |
| *Amila* (harvest) | 6 | 500 (tractor) |
| Cleaning | 3 (from household) | -- |
| **TOTAL** | **55-65** | **2100** |

**Oriya terms are italicized.*

**Table 5.** Approximate cost of labour to harvest 1 acre (as estimated by farmers in Tamana)

### 5.3. Agricultural Mechanization in Tamana

Of the seven small farmers interviewed, none owned bullocks because of their high maintenance costs. Instead they rent bullocks for Rs. 300 per day, plus the cost of food for the bullocks and the driver. It takes about 5 days to plough one acre (5 bhorono) using a pair of bullocks or about 8 days if the fields are flooded, as they are before the rice is transplanted at the end of the rainy season. Bullocks are used for ploughing, threshing and for manure but are especially ideal when plots are very small and it is inefficient to bring in machinery, there is no road access or the land is very uneven.

The small farmers interviewed also rented power tillers occasionally for ploughing and land preparation (tilling) and tractors for threshing and hauling (on occasion). RM rented a tiller from CTx GreEn to prepare his fields at a cost of Rs.200/hr, or about Rs.100/acre, given that it takes about one hour to till one acre of land. Overall the farmers felt that it is beneficial to rent a power tiller because it is approximately ten times more efficient than using a pair of bullocks for field preparation. It is also more efficient because bullocks are in high demand and often farmers must wait several days for bullocks, while there is a shorter wait period for tillers. Power tillers are better for soil preparation in Tamana than tractors which unearth too much soil and so tractor rental is infrequent unless there is a larger area of land where a tractor is efficient or in some cases where a tractor is favourable for threshing and hauling rice. There are two individuals in Tamana who own tractors. They charge Rs.500 per hour for rentals.

Despite the tiller being an efficient tool for threshing, the farmers interviewed preferred to use bullocks or rent a tractor for their threshing needs, due to village beliefs regarding the inefficiency of tillers for threshing. The farmers interviewed would consider using the tiller for threshing if it was readily available and if demonstrations were provided. AP noted that if a group of farmers were to purchase a tiller it would be more worthwhile than an individual purchasing it alone because the tiller would spend more time in use and could thresh many people's paddy. All the farmers indicated that they plan to rent a tiller again, mainly because they do not have to chase after the bullock owner and secondly because a tractor unearths too much land. Interviewees reported that, if farmers can all agree on a day to rent the tiller for threshing, instead of buying a tiller, and then they could all benefit from faster threshing.

# 6. Two Scales of Biodiesel Production in Orissa

## 6.1. Micro Scale: CTx GreEn

**CTx GreEn**, or Community-based Technologies Exchange fostering Green Energy Partnerships, is a Non-Governmental Organization based in Kitchener, Ontario and operating in Orissa, India. In February of 2004, CTx GreEn opened a biodiesel pilot plant near Mohuda, Orissa on the grounds of **Gram Vikas**, an established rural health and sanitation NGO. Gram Vikas has been working with villages in Orissa for over 30 years, primarily focused on bringing running water to communities for improvement of livelihoods. Through the MANTRA approach, Movement and Action Network for the Transformation of Rural Areas, Gram Vikas hopes to reach one percent of Orissan homes in the next decade (Gram Vikas, 2009).

### *6.1.1. History and Background*

Prior to 2004, CTx GreEn founders Ramani Sankaranarayanan (RS) and Geeta Vaidyanathan (GV) worked on a contract for Gram Vikas. During this time, they visited Kalahandi district in Orissa to see Gram Vikas' Rural Health and Environment Programme (RHEP) in practice. During the visit, they noticed that *Niger* seed was being collected and sold to middlemen for cash but could instead be used for value addition activities within the local area. Meanwhile, the Gram Vikas Rural Health and Environment Programme required running water to implement its sanitation projects but Kalahandi was not yet on the national energy grid. Therefore, there was a recognized opportunity and need for renewable energy to pump water to villages without having to rely on the government's rural electrification programme. The idea to harvest underutilized oil seeds to produce biodiesel for energy generation became the focus of an application to the World Bank Development Market Place competition, which was awarded to CTx GreEn in 2003. In February of the following year, the Gram Vikas-CTx GreEn biodiesel project was inaugurated.

The location of the pilot plant was chosen because of affiliation with Gram Vikas. The village locations where the biodiesel project were first implemented, being Kinchlingi and Kandabanta-

Talataila, were chosen alternately because of farmers' willingness to take risks, access to underutilized oil seeds and requirements for renewable energy (Vaidyanathan, 2009, p. 77). The pilot plant was originally set up for development of technology, machinery and biodiesel recipes and to train "barefoot technicians" to disseminate knowledge at the village level. According to Vaidyanathan (2009), "[a]nother role of the pilot plant is to develop good operating practices to manage and monitor the technology, and its impact on the community" (p. 73). The CTx GreEn "strategy for the future is to transform the pilot plant into a resource centre for biofuel-based livelihood strategies" (CTx GreEn, 2009).

Biodiesel production began at the Mohuda pilot plant as early as April 2004 with 5L batches. The first 20L batches were produced in May 2004 and biodiesel production in the first village of Kinchlingi began in November 2004, followed shortly by the twin villages of Kandhabanta and Talataila in December 2004. Due to the micro scale nature of the biodiesel production, the process became known as Village Level Biodiesel, or VLB. Initially, the drivers of VLB were to provide electricity for Gram Vikas' RHEP in Kalahandi District though the project goals quickly extended to livelihood development and value-added economic activities in the communities.

### *6.1.2. The Production Process*

The current mantra of the GV-CTxGreEn biodiesel project is, "local production for local use" to move villagers from subsistence activities to economic activities that fuel livelihood benefits (Vaidyanathan, 2009, p. 48). From an environmental perspective, locally sourced and produced renewable energy can be used for daily activities such as water pumping in place of villages relying on a connection to the electrical grid, which is slow to be implemented in rural Orissa. Under the Government of Orissa's Rajeev Ghandi Grameen Vidyutikaran Yojana (RGGVY) programme launched in 2005, the state aimed to provide subsidised electricity to all villages of over 100 individuals by 2010. Another programme called Biju Gram Jyoti is in place to electrify villages of 100 individuals or less. As of 2008, the Government of Orissa Energy Department, this goal was not yet achieved, though detailed numbers have not been provided in the Annual Report (GoO, DEn, 2008).

The biodiesel project promotes rural energy security by providing a reliable energy source to fuel livelihoods. It promotes and maintains food security by increasing incomes through entrepreneur activities and by providing value added products from underutilized resources, such as biodiesel, soap and oil cake. Access to energy from biodiesel can pump water and provide household lighting, and the use of biodiesel in agricultural mechanization can increase the speed and efficiency of crop sowing.

Seeds for biodiesel production are mainly collected from the forests near villages by the villagers themselves. On occasion, the biodiesel project has purchased seeds from villagers for use in research and testing activities. In the villages that have manual oil presses, the seeds are pressed and processed on site using a pedal powered reactor. Samples of the biodiesel produced in the villages are sent to the Mohuda pilot plant for basic quality testing to ensure that the VLB meets Indian quality standards established by the Bureau of Indian Standards (described in GoI, MNRE, 2008, p. 14).

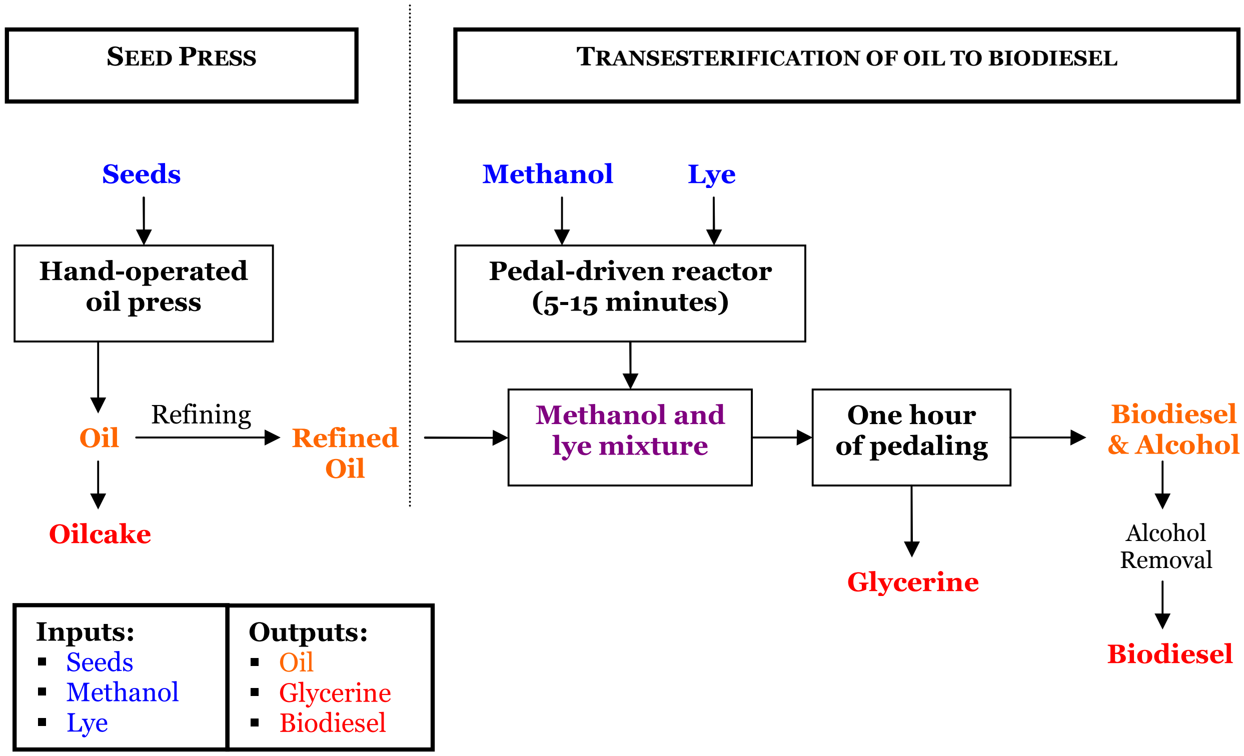
The local seeds used to produce biodiesel are both edible and non-edible. Edible seed options include *Madhuca indica* (Mahua), *Guizotia abysinnica* (Niger) and *Ricinus communis* (Castor). Non-edible are *Pongamia pinnata* (Karanja), *Schleichera oleosa* (Kusum). Differing amounts of each type of seed are required to produce one batch of biodiesel but the average yield of oil per seed ranges from 22-38%. To produce one batch of biodiesel at this scale, between 4 and 8 grams of lye are required, constituting less than 1% of the total chemical mixture. The oil makes up approximately 75% of the mixture and the rest is made up of methanol (~24-26%).

| **Input** | **Percentage of Total Mixture (%)** |
|---|---|
| Oil | ~75 |
| Lye | <1 |
| Methanol | ~25 |

(CTx GreEn, personal communication, 2009-2010)

**Table 6.** Inputs for biodiesel production, CTx GreEn

The process of producing biodiesel using VLB methodology occurs in two stages [Figure 6]. The first stage requires washing and de-hulling the seeds, pressing them in a manual powered oil press and refining the oil. A by-product of this process is produced from the skins of the seeds, which are formed into oil cakes and can be sold, employed as fertilizer or used as animal feed. The second stage in the production process is transesterification of the oil, which takes about four hours from start to finish. First, the lye (sodium hydroxide or potassium hydroxide) is mixed with an alcohol (methanol or ethanol) in a small reactor by pedal power for five minutes. Then, the oil is added to the lye-methanol mixture and one hour of pedaling allows the full reaction to take place. The mixture separates in about two hours: glycerine settles at the bottom of the tank and biodiesel and alcohol settle on top, due to differing densities. The biodiesel-alcohol mixture is distilled to remove the alcohol and a fuel very close to B100 (where the number, in this case 100, represents the percentage of biodiesel in the mixture) is left. The biodiesel that is produced can be used in generators and pump sets for water pumping and household lighting. In the past, CTx GreEn has not recovered the alcohol from the distillation process, though this is beginning to take place (2010). The glycerine, a by-product of the second stage, can be composted, sold or used in soap-making. Future plans include alcohol recovery for the purposes of creating ethanol to be used in cooking stoves (CTx GreEn, personal communication, 2009-2010).




(CTx GreEn, personal communication, 2010)

**Figure 6.** CTx GreEn Biodiesel Production Process

### *6.1.3. Achievements*

Since 2004, CTx GreEn has successfully introduced village-level biodiesel production in two locations in Orissa: Kinchlingi and Kandhabanta-Talataila. In Kinchlingi, 25,000,000 litres of water was supplied over three years using biodiesel until a gravity flow water system was introduced in the village in 2008. The project has been run using what CTx GreEn has dubbed "sweat equity": "[e]ach household provides one volunteer, one day per month to run and maintain the oil press and the biodiesel reactor" (with assistance from a trained barefoot technician) (CTx GreEn, 2009, p. 3). The biomass source used in Kinchlingi is Niger, which was cultivated by volunteers on rotation. Niger is a short duration, 120-day non-intensive crop that was grown on four acres of fallow land (land that was not cultivated for over three years). Villagers also exchanged salt with another village for Karanja, a non-edible oil seed. Villager volunteers produced 11-13 litres a month from May 2005 to April 2008 for water supply. 470

litres of biodiesel provided 700 hours of pumping. Also, 13 litres of biodiesel a month provided hybrid lighting from January 2009. The women who are freed from fetching water for household needs (since access to pumped water became available) have been motivated to engage in glycerine-based soap making initiatives, using the by-products of biodiesel production. There has also been discussion in Kinchlingi about producing biodiesel to fuel a power tiller to facilitate cultivation (CTx GreEn, 2009)

In the twin villages of Kandhabanta-Talataila (KT), biodiesel production has been operated and managed by a self-help group, assisted by a barefoot technician (trained by CTx GreEn). In KT, 92 litres of biodiesel provided 150 hours of pumping and 500,000 litres of water were supplied by biodiesel over a seven-month period, until a gravity flow system was introduced in 2007. Five acres of Niger crop were cultivated. Approximately 13 litres of biodiesel per month was produced from July to August 2006 and December 2006 to May 2007. Women in KT also have more free time to engage in livelihood development activities. As a result of the VLB, Niger has become an edible oil crop in the local area (CTx GreEn, 2009).

### *6.1.4. Village Level Biodiesel (VLB)*

The start-up costs for the project, including all machinery costs, were sourced from the World Bank Development Market Place 2003 Award, which spanned from 2004 to mid 2005. In 2007, the Shastri Indo-Canadian Institute awarded a Millennium Development Goals Research Grant jointly to Dr. Susan Wismer of the University of Waterloo and Ramani Sankaranarayanan of CTx GreEn for "[l]inking people to land regeneration through livelihood-reinforcing energy services" (Shastri Indo-Canadian Institute, 2009). The Swiss Development Corporation (SDC) provided training and salary support from 2007 to 2009 and provided support for print and video documentation in 2009 (CTx GreEn, personal communication, 2009).

The current goal for the VLB project is replication, providing opportunities for other villages to develop their own VLB operations. A key component of the replication initiative is establishment of an enterprise model for biodiesel production and consumption for livelihood development known as a "local production for local use enterprise driven model (CTx GreEn, personal communication, 2009). The major obstacles that the project faces in reaching this goal are funding for training and financial buffering from start-up to breakeven points in enterprise development, identification of and generation of support from potential entrepreneurs in villages and finally, procurement of seeds for sustainable biofuel production.

## 6.2. Mid Scale: Bhubaneshwar Integrated Biodiesel Plant

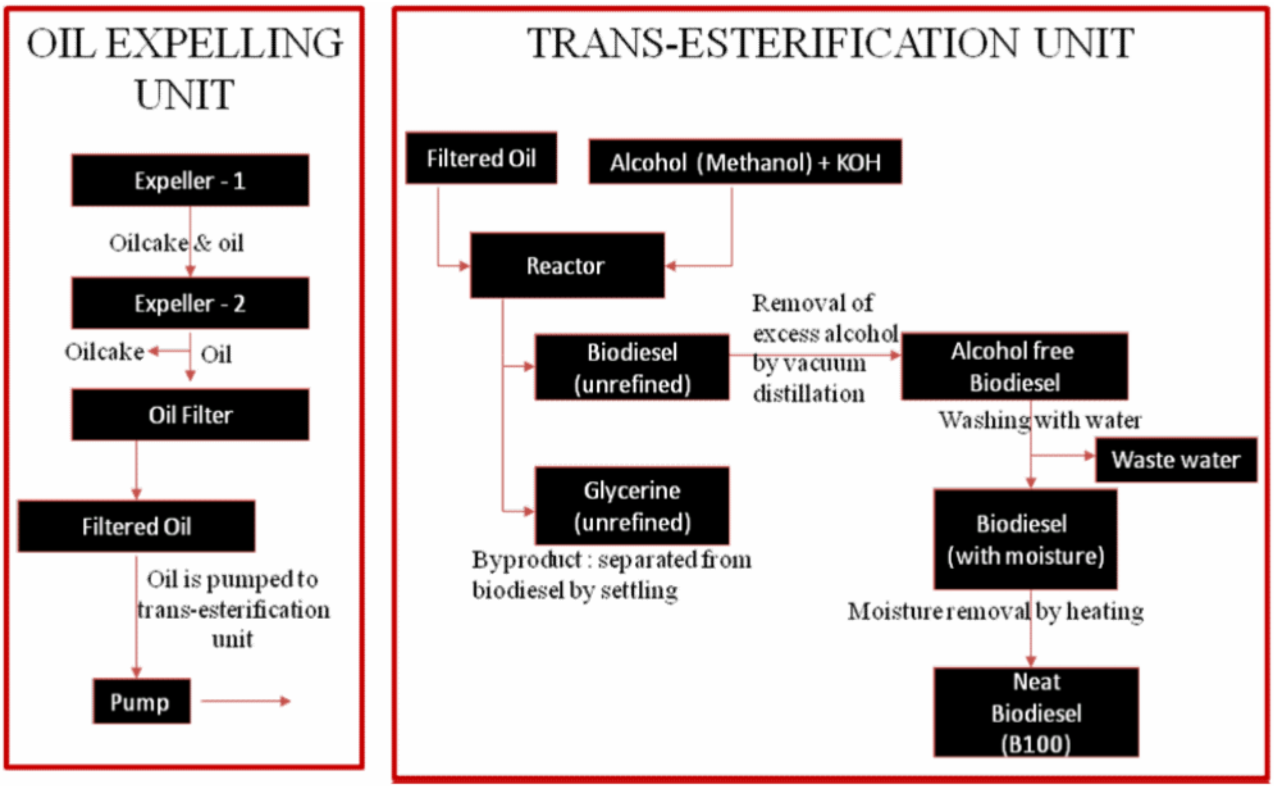
### *6.2.1. History and Background*

The Orissa Forest Development Corporation (OFDC) integrated biodiesel plant is a renewable energy initiative supported by the Government of India's Department for Science and Technology (IDST). The plant was installed in Bhubaneshwar, Orissa by the OFDC with technical help from IIT New Delhi and the Orissa University of Agriculture and Technology (OUAT) in Bhubaneshwar. The purpose of the plant according to the OFDC is "…to promote the production and utilization of [b]io-diesel from non edible seeds like Karanja, (porgania pinnale[*sic*]) Jatropha seed and its application in [a]griculture" (OFDC, n.d.). MKM, a professor in the College of Agricultural Engineering and Technology at OUAT indicated that another intended purpose of the plant is to increase awareness of biodiesel in the state. IDST hoped that by locating the plant in the heart of Orissa's capital they might better achieve this goal.

The project, referred to in this research, as the Bhubaneshwar (BBS) pilot plant, was commissioned by the IDST on October 10, 2006 and was inaugurated by the Chief Secretary of Orissa on May 2, 2007. The costs associated were covered entirely by the IDST, including 8 *lakh* for building costs and 19 *lakh* for machinery costs - which amounts to $18, 020 and $42,810 CAD respectively, for an approximate total cost of $60,830 CAD (where 1 *lakh* = 100,000).

### *6.2.2. The Production Process*

Production began at the pilot plant in May of 2007, managed by MKM of OUAT. The production capacity of biodiesel at the BBS plant is 150kg, though this threshold has not yet been reached (2010). One batch of biodiesel, averaging between 120 and 140kg, requires two work days with two regular labourers and one skilled labourer. MKM has produced about ten batches of biodiesel to date with the help of his students. The biodiesel is produced in two stages, first passing through the oil expelling unit and then through the trans-esterification unit (seen in Figure 7). This process is done entirely by machine as opposed to the CTx GreEn process, which runs on human power.




(MKM, personal communication, 2009)

**Figure 7.** Biodiesel production process, BBS plant

The biodiesel produced at the BBS plant thus far has been solely from *Karanja* oil, extracted from *Pongamia Pinnata*, or simply the *Karanja* seed. This is different from the CTxGreEn project where several types of oilseeds, including *Karanja*, have been used in biodiesel production. For production at the plant thus far, the *Karanja* seeds have been purchased by IDST at an approximate cost of 13-14 Rs/kg. At this rate it is not cost effective to produce biodiesel for sale as a replacement for diesel (MKM, personal communication, 2010). For this reason, MKM notes that it has been impossible to begin real production of biodiesel at the plant without a buyer and it seems that buyers are not willing to pay the more expensive price of the biodiesel. As such, the project reached a standstill in 2009, presumably until it can locate cheaper seeds, procure a buyer and or lower the cost of production. This last element is important as the cost of the final biodiesel is impacted not only by the initial cost of the seed, but also by the cost of the alcohol and lye which are used as catalysts in the production process. Whereas CTxGreEn is currently attempting to regain some cost from the sale of by products, including oil cake and glycerine, OUAT has indicated that it disposes of its waste glycerine and has not looked into the sale of either by-product. At this point in time, estimates of costs and potential recovery revenues from the sale or recycling of inputs are not available from CTx GreEn or OUAT, though it is reasonable to deduce that revenues from any of these activities could help to offset production costs.

Using the plant as a training and demonstration centre, MKM has instructed several students in the Bachelor of Technology (B. Tech) and Master of Technology (M. Tech) programs at OUAT on how to produce biodiesel and manage the plant on their own. These students have run many tests, in and out of class time, to determine the density, the boiling point and the viscosity of the biodiesel produced at the plant. These values have been collected for both scientific and academic purposes. The biodiesel produced at the plant has also been subjected to emissions tests at OUAT by both students and professors in order to study emissions from *Karanja* based biodiesel. The specifications of the biodiesel from the plant are reproduced in Table 7.

| No. | Properties | Unit | Diesel | Karanja Oil | Karanja Biodiesel |
|---|---|---|---|---|---|
| 1 | Density | kg/L | 0.835 | 0.92 | 0.89 |
| 2 | Kinematic viscosity (@ 380°C) | CST | 3.01 | 46.48 | 6.87 |
| 3 | Calorific value | MJ/kg | 42.8 | 38.8 | 37.9 |
| 4 | Flash point | °C | 50 | 248 | 180 |

(MKM, personal communication, 2009)

**Table 7.** Properties of Diesel, Karanja oil and Karanja biodiesel, BBS plant

### *6.2.3. Future Considerations*

The project was originally intended to provide biodiesel to fuel department busses at the OFDC and potentially at the IDST in order to reduce GHG emissions; however this has not yet come to fruition. Instead, it is hoped that the biodiesel plant will continue to function as a demonstration plant and will sell its biodiesel to a private entrepreneur. As of March 2010, the plant is producing biodiesel intermittently for academic purposes at OUAT.

### 6.3. Summary

This section has detailed two scales of biodiesel production in Orissa: village level and mid-scale industrial. Such examples remain scarce is Orissa and in India as a whole, as biofuel development is centred on large-scale processes. This is largely because the National Biodiesel Policy indirectly promotes large-scale biodiesel production, particularly to meet its goal of 20 percent blending by 2017. Secondly, economies of scale in production are required in order to make profits. This is especially true in cases where producers intend to export biofuel to burgeoning markets in the EU and US.

The BBS biodiesel project exemplifies a typical concern for sustainable biofuel production: procurement of seeds. Biodiesel production stands the greatest chances of success when it remains at a scale that matches seed availability. In the case of the CTx GreEn VLB, seed procurement is also key, however, at the village level with lower quantity requirements and flexibility in choice of plant sources, it is possible to cultivate oilseeds on marginal land and in household gardens, which can satisfy community biodiesel needs.

# 7. Summary and Conclusions

This research addressed the potential to integrate mitigation and adaptation mechanisms for climate change by coupling village based biodiesel production with custom hiring of agricultural machinery in rural India. The key findings indicate that this type of arrangement can allow farmers to improve timeliness of sowing while enhancing community development and providing livelihood benefits.

Adaptation mechanisms are important to ensure livelihoods for the future in the face of changing climate. In Orissa, warming temperatures, erratic monsoon and out-of-season rains have affected crop development (Jaswal, 2010). One potential adaptation mechanism described in this research includes the use of machinery to efficiently facilitate agricultural activities in place of human and draught animal power.

Mechanization using conventional fossil fuel can lead to an increase in greenhouse gas emissions; however, using sustainably sourced biodiesel as a replacement provides a unique opportunity for mitigation. Farmers can take advantage of machinery to facilitate agriculture in a sustainable manner. Meanwhile, promoting availability of machinery through custom hire can contribute to the long-term success of subsistence agriculture based on marginally sized land holdings. In the case of Tamana, the majority of farmers own marginal land that does not lend itself to the purchase of machinery. In the absence of a major political campaign for land reform to equalize the size of land holdings, custom hiring of tractors and tillers is an attractive option to promote successful yields on small tracts of land.

Agriculture is the driving force behind India's economy and is a livelihood source for 58 percent of the working population (Puttaswamaiah et al., 2005). India's high vulnerability to climate change highlights the importance of sustainable agriculture, both as an adaptation mechanism and to limit greenhouse gas emissions (Parry et al., 2007). The volatility of subsistence agriculture is also exemplified in the case of Tamana, where everyone is primarily supported by a yearly rice crop. Agricultural practices in Tamana remain small scale and family oriented; however, there is also widespread use of pesticide and fertilizer. It is imperative that the

Government of India enforce its policies on sustainable agriculture at the community level, in order to ensure that families can continue to subsist on their land in the future. This can be achieved by educating farmers about various sustainable practices available and applicable in India. Sustainable agriculture can limit use of pesticide and fertilizer and can be cheaper and more productive in the long run (Pretty et al., 2002).

Tractors and power tillers are becoming more prevalent in Indian agriculture while reliance on draught animals is decreasing. As mechanization rises, the share of diesel consumed for agricultural purposes will follow suit. Mechanized agriculture can dramatically increase the efficiency of field preparation but it is necessary that increasing mechanization come hand in hand with sustainable agriculture and sustainable energy consumption. Sustainable energy sources can be made available in order to limit a steep rise in fossil fuel consumption from agricultural practices.

Khan et al. (2007) outline a sustainability assessment for community-based energy technologies centered on an infinite timescale. Based on this assessment, where biodiesel source seeds are available naturally in sufficient quantity to support a village-level biodiesel production system, biodiesel can be ecologically, economically and socially appropriate as an energy technology. The Gandhian principle of appropriate technology, is concerned with matching technological development at the grassroots level to the contextualized needs of communities (Bakker, 1990). Promoting rural technology creates jobs and disseminates knowledge, ultimately enhancing community and socio-economic development. From a development perspective, keeping technological, developmental and socio-economic innovation in the hands of the community will ensure that all benefits are enjoyed at the local level.

Tamana exemplifies a unique opportunity for mechanization to be part of a solution rather than a problem. An entrepreneurial farmer can run a custom-hire business to earn money and also allow other farmers to benefit from local access to machinery. Alongside this, a biodiesel production business using locally sourced, indigenous oilseeds can provide a sustainable fuel suitable for use in machinery. In addition, both businesses contribute social and economic benefits in the forms of skill development and cash income. This research describes a great opportunity available to farmers in Tamana who are willing to take on this business model. If applied, it can lead to a winning situation for the entrepreneur, other farmers and the community as a whole.

The case study described in this research is unique; however it can be used to infer opportunities that may be applicable elsewhere. For example, replacing conventional fossil fuel with locally sourced biodiesel is an option that is available anywhere there is an abundance of adequate indigenous oilseeds for biodiesel production. Similarly, using biodiesel in agricultural machinery is a possibility anywhere machinery is run on conventional diesel. However, each situation is context specific and the scale of biodiesel production must not exceed the availability of seeds, in order to remain sustainable over the long term. The cultural approach should also differ in order to maintain relevance to the local context.

The role of Non-Governmental Organizations can be very beneficial to the dissemination of appropriate rural technology. In the case of Tamana, NGOs have been a driving force but have also done well to ensure that the means of control, financially and logistically, has remained in the hands of locals. Gram Vikas is a highly functional organization whose altruistic goals are being achieved one day at a time with overwhelming success. Many other community development organizations across India and abroad can learn from Gram Vikas and perhaps it is their duty to spread their successes elsewhere. CTx GreEn, on a similar note, has managed to convey the complexities of rural energy technology in a way that has allowed villages to claim this technology as their own—embodying the values of Gandhi's appropriate technology. CTx GreEn too is charged with spreading both its values and its message to engage other communities in embracing localized energy autonomy, a task which the organization is taking on with zeal.

Further research is required to adequately assess each type of oilseed for its oil to seed ratio and its end use energy production. This data should then be subjected to a sustainability assessment for community-based energy technology outlined in Khan et al. (2007). A true calculation of the amount of diesel consumed in agricultural machinery is necessary for a more accurate understanding of how much biodiesel is required as a replacement. Similarly, the number of machines available in Indian agriculture remains speculation, making it difficult to quantify the diesel requirements of these machines alone.

The importance of a small-scale approach to climate change remains insufficiently addressed in climate change literature and grey material. The predominant approach to climate change mitigation mechanisms has been top-down, mandated at the global and national levels. Adaptation has taken a more community-based route, as each community has a different set of climate concerns. Integrating both mitigation and adaptation mechanisms at the local level increases community resiliency to climate change and can also provide various ecological, economic and social benefits. Climate change is a global concern, and despite the unequal distribution of cause, it affects every nation and individual. It may take decades for an international treaty such as the United Nations Framework Convention on Climate Change to legally bind nations to emission reductions that will be strong enough to limit the rate of climate change. In the meantime, communities must take matters into their own hands where appropriate, implementing mechanisms and opportunities that increase adaptive capacity and also limit the release of new greenhouse gas emissions into the atmosphere.

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# Appendix

## Comparison of Scales of Biodiesel Production in Orissa, India

| | | *CTx GreEn*<br>**Village Level Biodiesel (VLB)** | *OFDC/DST/OUAT*<br>**Integrated Biodiesel Plant** |
|---|---|---|---|
| | **Scale** | Village based | Midsize |
| | **Location** | Mohuda, Orissa (pilot plant) | Bhubaneshwar, Orissa |
| | **Production began** | February 2004 | May 2007 |
| | **Batch size** | 5 L and 20 L | 80-85 L |
| | **Time/batch** | ~ 4 hours | 2 days @ 8 hrs/day → 16 hours |
| | **Machinery** | ▪ Hand powered oil press<br>▪ Oil refining filter<br>▪ Pedal powered reactor<br>▪ Distillation unit | ▪ Mechanical oil expeller unit (x 2)<br>▪ Oil filter<br>▪ Oil pump<br>▪ Reaction unit (x 2)<br>▪ Washing unit (x 3)<br>▪ Reagent mixer<br>▪ Condenser<br>▪ Distillation unit (boiler)<br>▪ Alcohol recovery tank |
| Inputs per batch | **Seed** | 20-80 kg (dependent on seed) | 500 kg (only use of karanj) |
| | **Lye** | 4-8 g | 1010 g (1.01 kg) |
| | **Alcohol** | ~25% of total mixture | 30-50 L |
| Product end use | **Biodiesel** | ▪ Water pumping<br>▪ Household lighting<br>▪ Agricultural mechanization | ▪ Transportation for the Orissa Forest Development Corporation and the Department for Science and Technology |
| | **Glycerine** | ▪ Soap making | ▪ Discarded |
| | **Oil cake** | ▪ Fertilizer<br>▪ Local sale | ▪ Fertilizer on OUAT test fields |
| Cost | **Building** | ▪ *Unknown* | ▪ 8 lakh rupees = 18, 017 CAD |
| | **Machinery** | ▪ *Unknown* | ▪ 19 lakh rupees = 42,809 CAD |

Note: 1 lakh = 100,000; Conversions calculated using exchange rate on April 6, 2010 at 44.39 rupees to $1 CAD.

## Thesis Interview Log

| Date | Time | Location | Interviewee | General Topic | Notes |
|---|---|---|---|---|---|
| 11-23-2009 | 9:00-10:00 | Orissa University of Agriculture and Technology (OUAT), Second floor, Bhubaneshwar | MKM | OFDC/DST 150 L/batch biodiesel plant | |
| 11-23-2009 | 10:00-11:00 | Orissa University of Agriculture and Technology (OUAT), Second floor, Bhubaneshwar | SKN | Farm mechanization in Orissa; Use of tractors and power tillers in Orissa | |
| 11-24-2009 | 11:30-12:30 | Agricultural Promotion and Investment Corporation of Orissa Ltd. (APICOL), Baramunda, Bhubaneshwar, Orissa 751 003 (phone 0674 256 1203) | SB and MS | Mechanization subsidies in Orissa; Number of subsidized tractors and power tillers | Received a printout of subsidies given by APICOL (*called APICOL – Year Wise Achievement under Work Plan*) |
| 12-20-2009 | 9:00-10:30 | Tamana, Orissa | SM | Tour of Tamana by SM | Included a visit to the fields, the pond and the gravity flow water tank |
| 12-23-2009 | 7:00-7:30 | Mallick Home, Tamana, Orissa | RM | Meeting to set up focus groups with farmers and tiller owners in Tamana | Meetings set for early January 2010. |
| 1-02-2010 | 19:00-20:00 | Home of Geeta Vaidyanathan and Ramani Sankaranarayanan | Geeta Vaidyanathan (GV), Ramani Sankaranarayanan (RS) | Discussion of the CTx GreEn village-level biodiesel production process and model | |
| 1-03-2010 | 7:45-8:45 | Tamana community square, Tamana, Orissa | BM, KM, K | Discussion with tiller owners – uses of tiller, rental aspects, agriculture overview | Need to follow up on data collected – cross reference |
| 1-05-2010 | 8:00-8:45 | Tamana community square, Tamana, Orissa | AP, MM, RM | Discussion with tiller renters – uses of tiller, costs of agriculture, basic data collection | Need to follow up with RM on business aspects of tiller rental |
| 1-15-2010 to 1-16-2010 | | Visit to Bhubaneshwar: Research Centre for Development Cooperation (RCDC) | AA and GG | Collection of data on agriculture in Orissa | |
| 1-28-2010 | 19:00-20:30 | Tamana community square, Tamana, Orissa | CM and RM (farmers and tiller users) | Discussion about power tiller, business model, maintenance issues and fees for the tiller | |

## Sample Open-Ended Interview Questions for Farmers in Tamana

1. What is your name?
2. How many people live in your household?
    a. Who lives in your household?
3. What are the professions of those in the household?
4. How much land do you own/rent?
    a. What type of land is it?
5. How did you get this land?
6. What crops do you grow and how many (per season)?
    a. What time of year is each crop grown?
        i. Kharif
        ii. Rabi
        iii. In between (name?)
7. Do you grow crops for household use or to sell?
    a. Which crops are for household use, which are sold?
8. If crops are sold,
    a. How much is sold?
    b. At what price?
    c. Is there generally a profit for you?
9. If crops are grown for consumption,
    a. Are there shortfalls?
    b. Excess?
    c. What is done in each case?
10. What is the average cost of inputs for each harvest (per crop, per bhorono)?
    a. Fertilizer (# kg; Rs/kg)
    b. Seeds (# kg; Rs/Kg)
    c. (labour – more questions to follow)
11. What is the average yield for each crop that you grow?
12. What is the average time to prepare the soil for each crop?
13. Average time to sow each crop?
14. Average time to harvest each crop?
15. Do you irrigate your fields?
    a. How?
16. Do you hire labour at any point in the harvest? (soil prep/sowing/weeding/harvesting/post harvest)
    a. How much?
    b. At what cost?
    c. For how long?
    d. Where does the labour come from?
    e. Is it difficult to find labour?
        i. Is there a lot of migration of labour outside of the village?
17. Do you own/use draught animals at any point?
    a. When and how?
    b. How many?
    c. What is the maintenance requirement/cost to maintain bullocks?

18. Do you hire a tiller or tractor? **[If yes, see *]**
    a. How often?
    b. From where?
    c. For how long?
    d. At what price?
19. Do you feel it is beneficial to hire a power tiller for field preparation?
    a. Why or why not?
    b. Compared to a pair of bullocks?
20. Would use of mechanized tools in agriculture allow you to increase the number of harvests per year? If yes, what tools?
21. Do you use urea?
    a. Where do you get the urea?
    b. Would you use oil cake instead if it were available?
22. Would you consider using biodiesel in your machinery?
    a. Why or why not?
23. Would you consider being involved in biodiesel production?
    a. Why or why not?

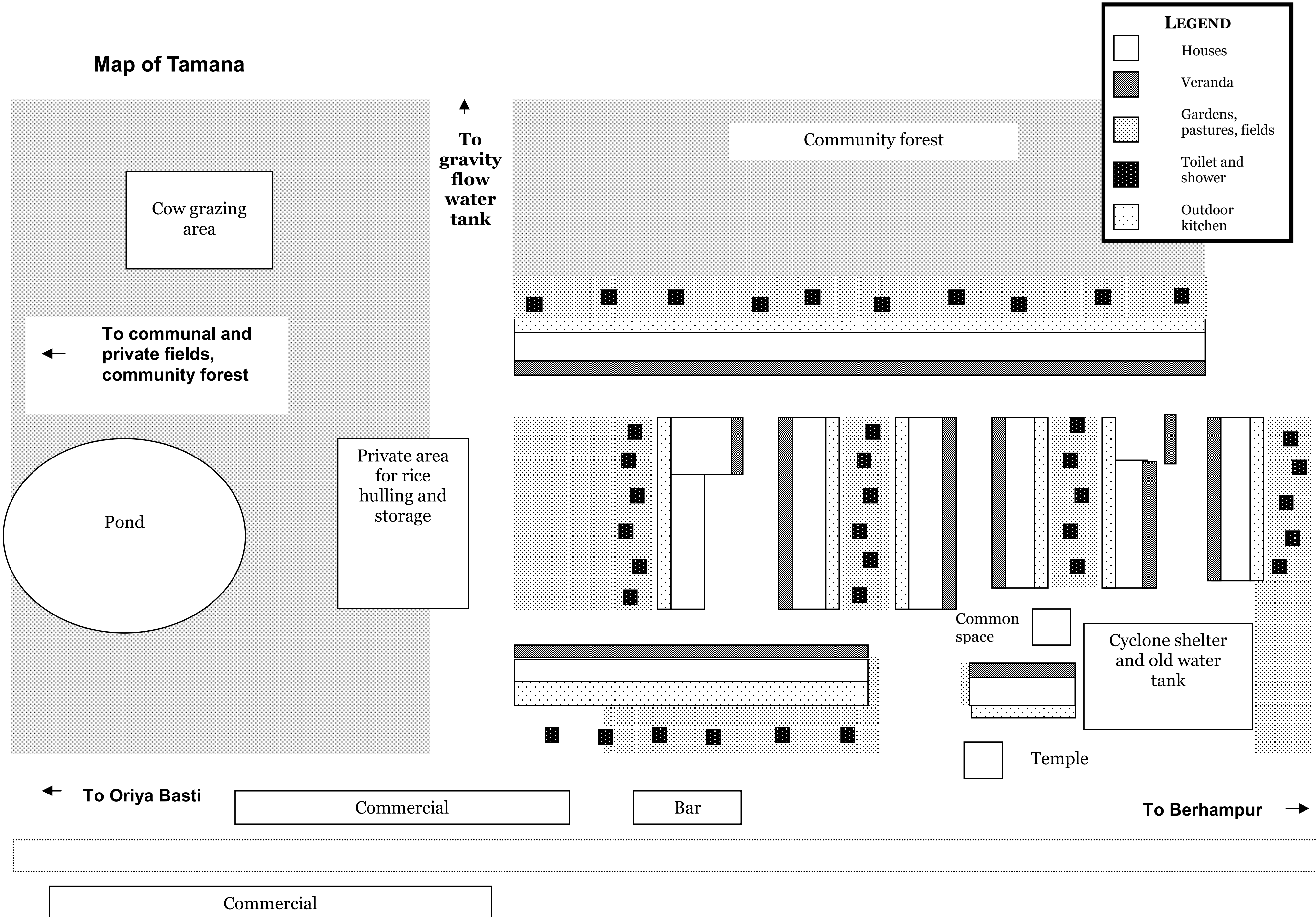
***Supplemental questions for those who have previously rented a tiller**

1. Why did you decide to use the tiller?
2. Was it beneficial to you?
3. If yes, how was it beneficial?
4. Did you save money?
5. Would you rent the tiller again this year?
6. If you could afford it, would you purchase your own tiller?

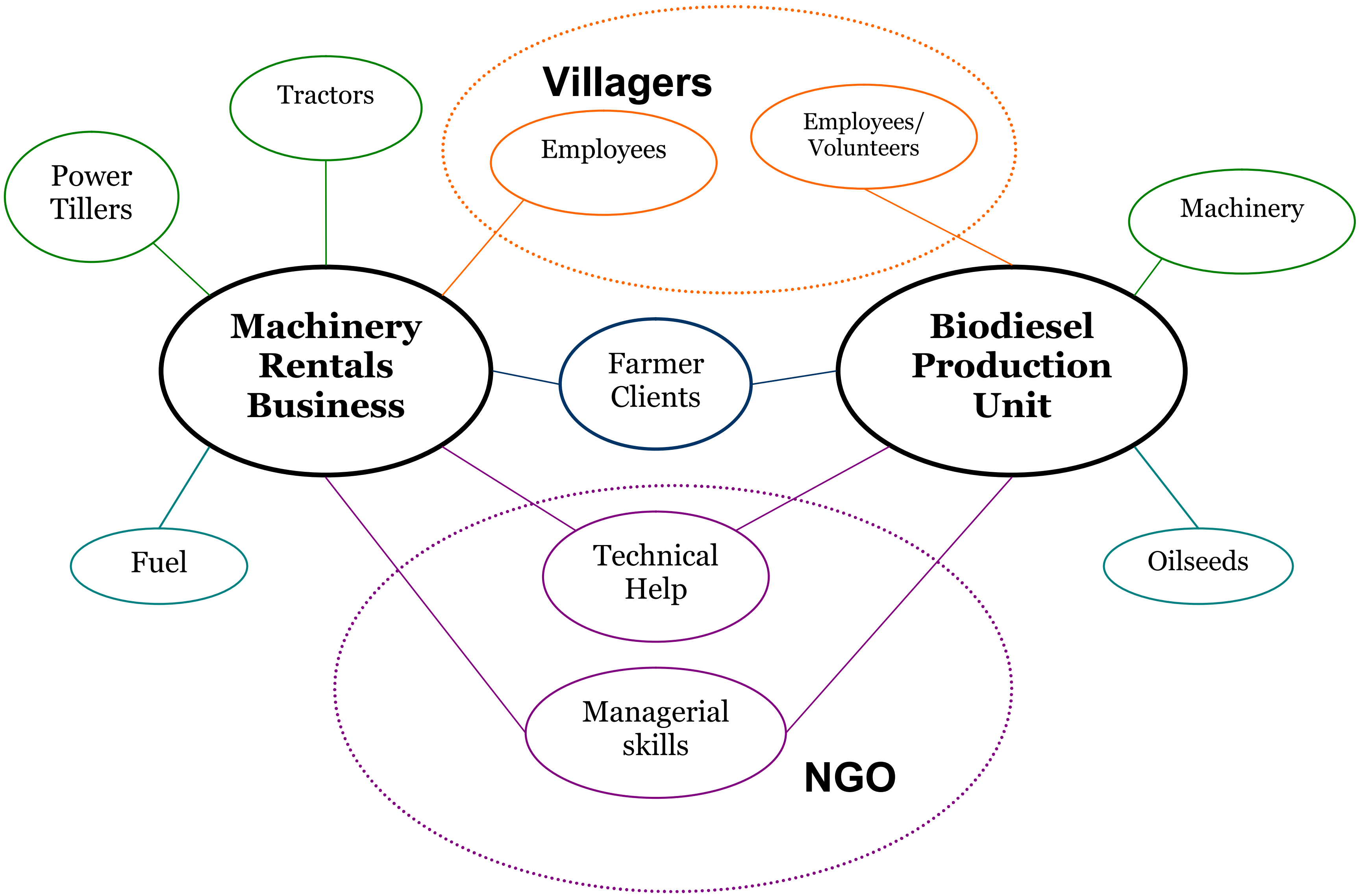
## Comparison of Agricultural Tools in Tamana, Orissa

<table>
<tr><th colspan="6">COMPARISON OF AGRICULTURAL TOOLS USED IN TAMANA, ORISSA<br>(1 acre = 5 bhorono) (Note: Numbers in Italics are provisional)</th></tr>
<tr><th colspan="2">ITEM</th><th>UNIT</th><th>DRAUGHT ANIMAL</th><th>POWER TILLER</th><th>TRACTOR</th></tr>
<tr><td rowspan="2">Time to plow</td><td>1 bhorono</td><td>Hours</td><td>4-5</td><td>0.5</td><td>0.2</td></tr>
<tr><td>1 acre</td><td>Hours</td><td>20-25</td><td>2.5</td><td>1</td></tr>
<tr><td colspan="2">Rental fees</td><td>Rs.</td><td>300/pair of animals and a driver; food for animals and driver are expected</td><td>200</td><td>500</td></tr>
<tr><td colspan="2">Cost of machinery</td><td>Rs.</td><td>20,000-30,000/pair</td><td>73,000 (with subsidy), minus additional subsidy of 15,000 → 58,000</td><td></td></tr>
<tr><td colspan="2">Duration of investment</td><td>Years</td><td>5-6</td><td>10+</td><td></td></tr>
<tr><td colspan="2">Maintenance costs</td><td>Rs.</td><td>▪ Food<br>▪ Shelter<br>▪ Medication</td><td>▪ 700-800 for servicing (x2)<br>▪ 8L of coolant<br>▪ 500-600 for plow servicing<br>▪ Total: ~1300-1500</td><td></td></tr>
<tr><td colspan="2" rowspan="2">Activities</td><td>Actual</td><td>Plowing and threshing</td><td>Plowing, carting</td><td>Plowing, carting, transportation</td></tr>
<tr><td>Potential</td><td>–</td><td>Irrigation, threshing</td><td></td></tr>
<tr><td colspan="2">Labour required</td><td># people</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td colspan="2">Cost of labour</td><td>Rs.</td><td>50-60</td><td>50-60</td><td>50-60</td></tr>
<tr><td colspan="2" rowspan="2">Diesel consumption</td><td>L/Acre</td><td>–</td><td>2-5</td><td>4</td></tr>
<tr><td>L/hr</td><td>–</td><td>1.5</td><td>4</td></tr>
<tr><td colspan="2">Advantages</td><td>–</td><td>▪ Cheapest investment at the outset<br>▪ Convenient for small plots of land; remote fields; uneven land</td><td>▪ Faster than using draught animals<br>▪ Cheaper than renting a tractor<br>▪ Can be used on remote fields without road access<br>▪ Can be used on uneven land<br>▪ Can be used to cart items</td><td>▪ Doubles as transport vehicle<br>▪ 2.5 times faster than a power tiller (plowing)<br>▪ 20-25 times faster than a pair of draught animals (plowing)</td></tr>
<tr><td colspan="2">Disadvantages</td><td>–</td><td>▪ Require constant care, feeding and maintenance<br>▪ Only active for 5-6 years</td><td>▪ Can be prohibitively expensive to own<br>▪ Requires diesel</td><td>▪ Highest investment at outset<br>▪ Not used for remote fields, uneven land, small plots<br>▪ Higher diesel consumption than a tiller</td></tr>
</table>

Map of Tamana



**Entrepreneurial Flowchart**



## Equivalent Coefficients of Various Energy Sources in Agriculture

| Energy source | Units | Equivalent energy, MJ |
|---|---|---|
| Human | Man-hour | 1.96 |
| | | 1 Adult woman=0.8 Adult man; 1 Child=0.5 Adult man |
| Animal | Pair-hour | 10.10 (Body weight 350-450 kg) |
| Diesel | litre | 56.31 |
| Electricity | kWh | 11.93 |
| Seed | kg | 14.7 |
| FYM | kg | 0.3 |
| Fertiliser | | |
| Nitrogen | kg | 60.6 |
| Phosphorus | kg | 11.1 |
| Potash | kg | 6.7 |
| Agro-chemicals | | |
| Superior chemicals | kg | 120 |
| | | Chemicals requiring dilution at the time of application |
| Inferior chemicals | kg | 10 |
| | | Chemicals not requiring dilution at the time of application |
| Machinery | | |
| Electric Motor | kg | 64.8 |
| Prime movers other than electric motors | kg | 68.4 |
| Farm machinery excluding self propelled machines | kg | 62.7 |

(Source: De, 2005, Pg. 350)