Comparison of GHG Emission in Rainfed and Irrigated Farming : *A Case Study in Gujarat*

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Swiss Agency for Development and Cooperation (SDC)
Swiss Cooperation Office India
Chandragupta Marg, Chanakyapuri
New Delhi 110 021 - India
Email : delhi@sdc.net
www.swiss-cooperation.admin.ch/india/

Prepared By

SATVIK
Promoting Ecological Farming

Satvik : Promoting Ecological Farming
26, Bankers Colony, Near Jubilee Ground,
Behind Syndicate Bank
Bhuj 370001 – Gujarat (India)
Email : satvik.india@gmail.com
www.satvik.org.in

Content

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Background

Since the culmination of the Green Revolution, India has reaped many of the benefits and faced many issues as a result of the agricultural overhaul. In the face of a changing climate, the problems of the past are becoming exacerbated. Arable land is at a premium in many parts of the country, water tables are low and many farmers face difficulty in sustaining their livelihoods. Yet in reckoning with food production in the future, it is necessary, in light of climate change, to consider the ramifications of agro-industrial greenhouse gas emissions and water use on future generations.

Rainfed farming, a system, as the name suggests, that relies solely on precipitation, has emerged as an alternative to the irrigated farming system. The most widely used method of farming for sustenance of farmers throughout India for long time, rainfed farming has largely been left out as food production is targeted. Instead, irrigation farming is the preferred method to produce as much food and as fast as possible. It is estimated by the Indian Council of Agricultural Research that, by 2013, India will reach its full irrigation potential, leaving over half of all farms in rainfed systems and still without the financial assistance to reach their full production potential.

As a result of focus on irrigated areas, millions of rainfed farmers do not qualify for the government schemes designed to help out farms and so toil without assistance and without guidance. Yet, there are many advantages of rainfed farming, which has great potential for increased production. Global studies show that small amounts of targeted investments have increased the production on rainfed farms many times over. With the large segment of the population involved in this form of farming, emphasis on the practice can solidify livelihoods throughout India. Since water is not used, water tables are protected for future generations and there are more resources for clean drinking water. Pulses, a central crop to the Indian diet, thrive on rainfed farms and there is increasingly a higher demand for this crop than the current production can support. These farms use less energy and chemical fertilizers. This study adds another potential data point, a lower rate of greenhouse gas emissions, to the mix of advantages that makes this farming system attractive to more attention and investment.

Study Specifics

This study, commissioned by the Swiss Agency for Development and Cooperation (SDC) and carried out by Satvik, an NGO based in Bhuj, Kutch, Gujarat, looked at emissions of greenhouse gasses (GHG) in irrigated farms and rainfed farms in Gujarat. Set in Gujarat because of its semi-arid and arid climate results in higher variability in weather patterns, the study was specifically interested in the additional costs to the environment caused by agricultural systems. This was achieved by comparing the CO2 equivalent production in practices of irrigated farms and rainfed farms. Additionally, in order to study the hypothetical results of increased investment, the study looked at what increasing production in each farming system would mean for GHG production and the use of water.

Findings were broken down into three major sections. GHG emissions were considered in both irrigated and rainfed farm system, looking at four categories of emitting activities – diesel use, electricity use from irrigation, chemical fertilizer application and compost use. This was further categorized by studying the resulting emissions in the cultivation of different crops throughout Gujarat. Taking this data on currently operating farms, we then extrapolated out what the resulting difference in emissions would be for increasing productivity on rainfed farms and on irrigated farms. Lastly, the study looked at water use currently being applied on farms as well as the increase in water use that is necessary to increase production.

The data shows trends about GHG production and water use. It was found that the average irrigated farm produces significantly more GHG than rainfed farms, both on a per acre basis and on 100 Kg of production. When upgrading rainfed farms for higher production, the resulting GHG production is less than the same kind of upgrading of an irrigated farm. For some crops, rainfed farms were even able to increase productivity while simultaneously reducing GHG emissions. In terms of water use, any increase of productivity on an irrigated farms results in an increase of water use.

Limitations

As this study is just a first step, designed to stimulate discussion as well as serve as a building block to bring this research to other parts of India and increase the number of farms surveyed, there are many limitations that must be acknowledged as they limit the conclusions that can be reached. The sample size, taken throughout Gujarat, is of oe year and relatively small and, when broken down further amongst different crop groups, is often too small to find trends. Productivity levels vary from farm to farm because of many different variables- on environmental, climatic and managerial levels.

Future

This study is exploratory and has narrow parameters aimed at adding to the discussion about providing food in a sustainable and environmentally-sensitive manner. Though statistically small and acknowledging its limitations, the study suggests that rainfed farming has less GHG emissions than irrigated farming and uses no water. With this initial data point in place, limited to one corner of India, it would be beneficial to expand this research to other parts of India to test these findings on a larger scale, addressing the complexity and the diversity of India's food production system.

Part I

Comparison of Green House Gas Emission in Rainfed and Irrigation Agriculture

Approach and Methodology

In order to compare Green House Gas (GHG) emission in rainfed and irrigation agriculture, a survey was conducted, analyzing energy use in farms by conducting sample survey spreading across state of Gujarat. The survey was taken over three seasons, the summer from March 2009 to June 2009, the monsoon season from July 2009 to October 2009 and the winter, from November 2009 to February 2010. Equal groups of irrigation farmers and rainfed farmers were selected and the study was tailored to match up crop specializations in each category.

Altogether, 19 villages were visited to study rainfed farming, spread out throughout 9 districts of Gujarat and 32 villages were included in the study of irrigation farming, in 12 districts. In total, 120 farmers were surveyed and 77 were ultimately included in the analysis. Survey forms which were incomplete are not included in the presented data. Additionally, due to lack of information on rainfed rice and cumin, these crops were not incorporated in analysis. Region wise, farming system wise and crop wise distribution of survey incorporated in analysis is given in Table 1.

Crop Name	Kachchh		Saurashtra		North Gujarat		South Gujarat		Total		Total
	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	
Pearl Millet	2	2	1	2	2	1			5	5	10
Maize							2	2	2	2	4
Green Gram	1	1			2	2			3	3	6
Red Gram			0	1			2	1	2	2	4
Sesamum	0	1	3	1					3	2	5
Castor	1	3	1	0	0	2			2	5	7
Sub Total	**4**	**7**	**5**	**4**	**4**	**5**	**4**	**3**	**17**	**19**	**36**
Cotton	**2**	**2**	**2**	**2**	**0**	**2**	**1**	**2**	**5**	**8**	**13**
Groundnut	**2**	**2**	**2**	**3**					**4**	**5**	**9**
Wheat			0	1	1	2	2	2	3	5	8
Bengal Gram			2	2					2	2	4
Sub Total	**0**	**0**	**2**	**3**	**1**	**2**	**2**	**2**	**5**	**7**	**12**
Mango		**1**		**1**					**0**	**2**	**2**
Sapota		**2**				**1**			**0**	**3**	**3**
Banana								**2**	**0**	**2**	**2**
Total	**8**	**14**	**11**	**13**	**5**	**10**	**7**	**9**	**31**	**46**	**77**
Region wise Total	**22**		**24**		**15**		**16**				

Table 1 : Distribution of Survey - Incorporated in Analysis

A total of 13 crops, including 3 horticulture crops, were analyzed. Since the number of farmers surveyed per crop was low, some crops were merged into crop groups as expressed in Table 2. Entries were arranged into crop/crop groups corresponding to the applicable farming system.

	No. of Farmers		Area Covered in Survey (Acre)		Survey Area per Farmer (Acre)	
	Rainfed Farming	Irrigated Farming	Rainfed Farming	Irrigated Farming	Rainfed Farming	Irrigated Farming
Pearl Millet, Maize, Green Gram, Red Gram, Sesamum and Castor	17	19	52.82	80.41	3.11	4.23
Cotton (Lint+Seed)	5	8	30	38.5	6.00	4.81
Groundnut (Pod)	4	5	25.2	25	6.30	5.00
Wheat and Bengal Gram	5	7	17.22	22.60	3.44	3.23
Mango		2		22.5		11.25
Sapota		3		9.01		3.00
Banana		2		3.8		1.90
Total	**31**	**46**	**125.24**	**201.82**		

In Gujarat usually horticulture crops are not cultivated in rainfed condition

Table 2 : Distribution of Survey - Farming System and Crop/Crop Groups wise with Profile

In regards to energy usage and soil fertility aspect, the following activities were identified for the study as activities that emit greenhouse gasses. Computation of resource use and emission in kilograms of CO2 equivalent was carried out.

- Diesel Consumption (See Annexure I for details)
- Chemical Fertilizers Application (See Annexure II)
  - In this study, the amount of emissions released in the industrial production of chemical fertilizers, which is high but not carried out at farms, is not taken into account.
- Electricity Consumption (See Annexure III)
- Compost Application (See Annexure IV)
  - While calculating, emission value of carbon sequestration was not taken into account.

Alongside the study of greenhouse gas emissions, water use in irrigation was competed. Detail of the assessment of irrigation water use is provided in Annexure V.

Survey form is Annexure VI

Ultimately, estimated values of GHG emission and water consumption was compared for rainfed and irrigated farming. Comparison was made at per acre and per 100 kilogram production. Variable of study was included for different crops/crop groups grown under the same farming system.

Analysis

Comparison of Production

Upon completion of the study, the rate of per acre productivity of seasonal crops in an irrigated farming system is 2.09 times higher than rainfed farming systems. The highest increase in productivity under irrigated conditions is observed in cotton, which has a rate 3.3 times that of rainfed farms. In groundnut production, the productivity is not statistically different. In horticulture per acre productivity, bananas grown under irrigated farming is 11.46 times higher than mangos grown under irrigated farming. Crop-specific detail is provided in Table 3.

	Production per Acre (Qtl.)		
	Rainfed Farming	Irrigated Farming	Increase Compare to Rainfed Farming/Mango
Pearl Millet, Maize, Green Gram, Red Gram, Sesamum and Castor	3.50	7.04	2.01
Cotton (Lint+Seed)	3.83	12.65	3.30
Groundnut (Pod)	7.34	7.32	1.00
Wheat and Bengal Gram	4.20	12.48	2.97
Mango		27.56	
Sapota		54.83	1.99
Banana		315.79	11.46

In Gujarat usually horticulture crops are not cultivated in rainfed condition

Table 3 : Crop/Crop Groups wise per Acre Production in Rainfed and Irrigated Farming System

Comparison of GHG Emission

Carbon dioxide, methane and nitrous oxide are the most common greenhouse gasses produced in agricultural production. Following the conversion suggestions made by the Intergovernmental

Panel on Climate Change (IPCC), the present study has factored in estimates of CO2-equivalent emissions by the different crops under the different systems. For comparison purposes, GHG emissions associated with consumption of diesel, application of chemical fertilizers and usage of electricity was used. Estimated CO2 equivalents GHG Emission - Crop/Crop Groups wise per Acre and per 100 Production Rainfed and Irrigated Farming System is provided in Table 4.

	CO2 equivalents GHG Emission per Acre per Season (Kg.)			CO2 equivalents GHG Emission per 100 Kg. Production (Kg.)		
	Rainfed Farming	Irrigated Farming	Increase Compare to Rainfed Farming/Mango	Rainfed Farming	Irrigated Farming	Increase Compare to Rainfed Farming/Mango
Pearl Millet, Maize, Green Gram, Red Gram, Sesamum and Castor	104.11	498.45	4.79	29.77	70.76	2.38
Cotton (Lint+Seed)	144.03	787.97	5.47	37.57	62.29	1.66
Groundnut (Pod)	71.23	845.52	11.87	9.7	115.51	11.91
Wheat and Bengal Gram	89.72	413.45	4.61	21.34	33.13	1.55
Average	**102.27**	**636.35**	**6.22**	**24.60**	**70.42**	**2.86**
Mango	-	591.82		-	21.48	
Sapota	-	1297.78	2.19	-	23.67	1.10
Banana	-	2900.26	4.90	-	9.18	0.43

Emission from Use of Diesel, Electricity and Chemical Fertilizers.

Table 4 : Estimated CO2 equivalents GHG Emission - Crop/Crop Groups wise per Acre and per 100 Production in Rainfed and Irrigated Farming System

Seasonal Crops

- Analysis of field data shows that the average per acre GHG emission in seasonal crops irrigated farming (636.35 Kg/acre) area is 6.22 times more than rainfed farm areas (102.3 kg/acre).
- Similarly for seasonal crop production on irrigated farms, per 100 kg, the process emits about 70.4 kg CO2 equivalent gases, about 2.9 times more than under rainfed conditions, estimated at about 24.6 kg CO2.
- Within the rainfed farming system, cotton, at 144.03 kg CO2 per acre and 37.57 kg CO2 per 100 kg production, is the highest GHG emitting crop while groundnut, 71.23 kg per acre and 9.7 kg per 100kg production, is the lowest.
- On irrigated farms, groundnut is the highest emitting crop, 845.5 kg per acre and 115.5 kg per 100 kg production and wheat and Bengal grams result in the least GHG production, 413.45 kg per acre and 33 kg per 100 kg production.

Horticulture Crops

GHG emissions from horticulture production areas have also been estimated, but due to lack of sufficient inputs, comparative analysis was only possible amongst different horticulture crops, rather than the farming systems. Therefore, Mango production has been used as a control to test the other crops for resultant emission levels.

- Using mango production emission levels of 591.8 kg per acre as a baseline, it was found that bananas have the highest level, at 2900 kg per acre.
- Emission from sapota growth is 1298 kg per acre, 2.2 times more than mango growing acres.
- From the productivity point of view, 9.18 kg of CO2 equivalent emission results from each 100 kg of bananas produced. That is 0.43 percent less than the rate for 100 kg of mangoes. Sapota, at 23.67 kg is 1.1 times more than the emission results for 100 kg of mangoes.

Comparison of Irrigation Water Use

As the names imply, irrigated farms rely on outside water sources and irrigation systems, whereas rainfed collects rainwater and therefore, the included farms do not use other water sources. In order to fully paint a picture of energy use and farming sustainability as it relates to the production of GHG emissions, it is important to include water use in the study. Study included an assessment of water use for each crop/crop group. Table 5 shows the estimated volume of water used per acre and per 100 kg production on irrigated farms.

	Irrigation Water Use per Acre per Season (CUM)			Irrigation Water Use per 100 Kg. Production (CUM)		
	Rainfed Farming	Irrigated Farming	Increase Compare to Pearl Millet etc/Mango	Rainfed Farming	Irrigated Farming	Increase Compare to Pearl Millet etc/Mango
Pearl Millet, Maize, Green Gram, Red Gram, Sesamum and Castor	-	1285.31		-	182.47	
Cotton (Lint+Seed)	-	1786.60	1.39	-	141.24	0.77
Groundnut (Pod)	-	1697.04	1.32	-	231.84	1.27
Wheat and Bengal Gram	-	1465.66	1.14	-	117.46	0.64
Average		**1558.65**			**168.25**	
Mango	-	701.16		-	25.45	
Sapota	-	3734.52	5.33	-	68.11	2.68
Banana	-	42972.63	61.29	-	136.08	5.35

Table 5 : Estimated Volume of Irrigation Water Used per Acre and per 100 Kg Production in Irrigated Farming System

- The average per acre water requirement of seasonal crop is about 1558 m^3
- In irrigated agriculture, per acre water use for groundnut cultivation is 1.32 times higher than the collective grains including pearl millet.
- The average water usage for per 100 kg of crop production of seasonal crop is about 168 m^3
- Per 100 kg of production water utilization for groundnut cultivation is 1.27 times higher than the pearl millet crop group cultivation
- For horticulture crops, the irrigation water use pattern is much higher for bananas and sapota. Per acre the bananas uses 61.29 times more water than the control, mangoes, and per 100 kg production of banana consumes 5.35 times higher water than mangoes.

Contributors of GHG Emission in Crops under Rainfed and Irrigated Farming System

When the emission factors are broken down into their contributing parts, the study can further deliver insight into the ways in which each farming system – and each crop – causes the production of GHG. Table 6 separates out the factors of GHG emission per 100 kg production in rainfed and irrigated farming systems.

Contributing Factor	CO2 eqivelent GHG Emission for 100 Kg Production (Kg.)	
	Rainfed Farming	Irrigated Farming
Diesel	9.94	9.04
Electricity	0.00	37.13
Fertilizer	14.64	24.21
Compost	1.41	1.38
Total	**25.99**	**71.76**

Table 6 : Factor wise Estimated GHG Emission for 100 Kg Production in Rainfed and Irrigated Farming System

Table 6 shows that crop production in rainfed condition emits a little more than a third of the CO_2 equivalents gases that irrigated production do.

- Emissions due to the use of fertilizers (14.64 kg or 56 %) and diesel (9.94 kg or 38 %) constitute the majority in rainfed production whereas, in irrigated production, the top two are electricity (37.13 kg or 51 %) and fertilizer (24.21 kg or 34 %).
- Diesel use is fairly similar, though rainfed farms use slightly more, 9.94 kg to irrigated farm's 9.04 kg.
- Rainfed production does not use electricity whereas irrigated production relies on electrical systems to control water supply. Therefore, a great deal more electrical power is used in irrigated farms.
- In rainfed production, the average fertilizer use is less than those at irrigated production, by about a half.

Crop-specific detail for factors contributing in GHG emission for rainfed and irrigated farming is provided in Figure 1.

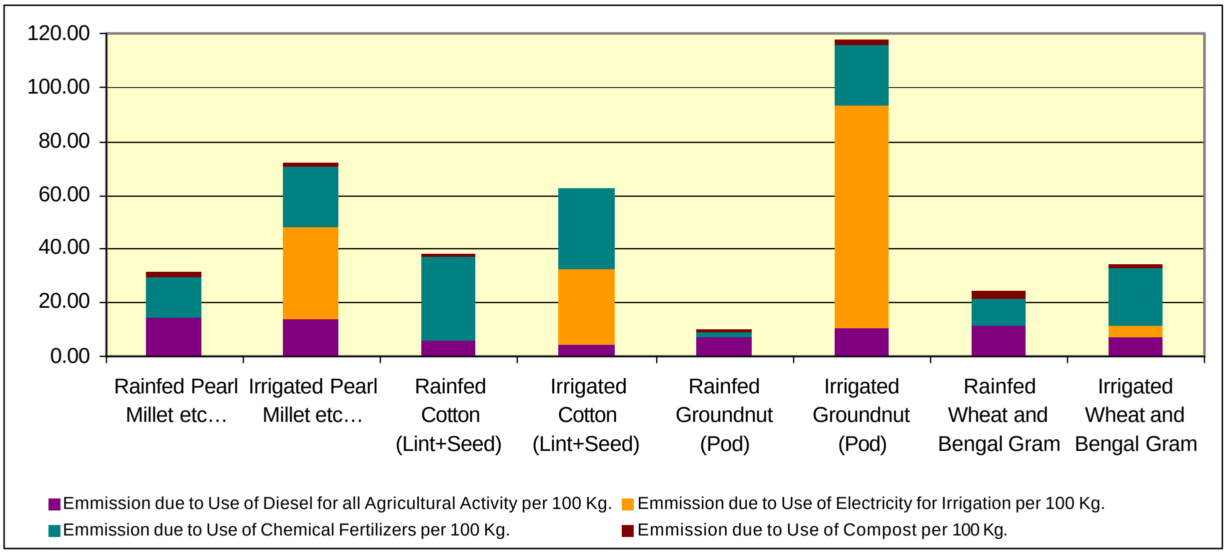


Figure 1 : Factor wise Estimated GHG Emission - Crop/Crop Groups wise per 100 Production in Rainfed and Irrigated Farming System

Part II

Changes in GHG Emission Corresponding to Increasing Productivity within the Farming Systems

Approach and Method

The second focus of this study looked at productivity rates of the two farming systems and the increase of CO2 equivalent GHG that is generated by any increase in crop production. Low and high productivity scenarios for different crops were carefully studied and water usage of irrigated farms was factored in separately as well.

To define the terms of the study, the average of productivity in selected farms has been used as the delineating line between those farms considered part of a low productivity scenario and those with high productivity scenarios. Note that the there are different reasons resulting in below-average or above-average scenarios and that the sample size continues to be small. Therefore, overarching conclusions are not to be reached on this data, but does provide an initial baseline for future studies in Gujarat and other states of India.

For this purpose, survey inputs and data points prepared for analysis under part I were plugged in to produce statistics for ‘production below average’, a low productivity scenario and ‘production above average’, a high productivity scenario. Detail is given in Table 7. As agricultural productivity needs increase, this study allows for extrapolation of production of GHG during expansion of farming operations. This exercise only studied the previously listed seasonal crops, though not on horticultural crops, due to a lack of volume of production in Gujarat.

	No. of Farmers				Area Covered in Survey (Acre)				Survey Area per Farmer (Acre)			
	Rainfed Farming		Irrigated Farming		Rainfed Farming		Irrigated Farming		Rainfed Farming		Irrigated Farming	
	Below Average	Above Average	Below Average	Above Average	Below Average	Above Average	Below Average	Above Average	Below Average	Above Average	Below Average	Above Average
Pearl Millet, Maize, Green Gram, Red Gram, Sesamum and Castor	10	7	11	8	27.00	25.82	51.96	28.45	2.70	3.69	4.72	3.56
Cotton (Lint+Seed)	2	3	3	5	15.00	15.00	9.10	29.40	7.50	5.00	3.03	5.88
Groundnut (Pod)	2	2	2	3	12.00	13.20	14.00	11.00	6.00	6.60	7.00	3.67
Wheat and Bengal Gram	3	2	3	4	13.22	4.00	10.60	12.00	4.41	2.00	3.53	3.00
Total	**17**	**14**	**19**	**20**	**67.22**	**58.02**	**85.66**	**80.85**				

Table 7 : Distribution of Survey - Farming System, Productivity Scenario and Crop/Crop Groups wise with Profile

Analysis

Change in Production

In rainfed farming, yield under the high productivity scenario is 1.78 times higher than the low productivity scenario. The highest increase in productivity is observed in case of the pearl millet group, which is 2.84 times high, while groundnut production increases the least, at a rate of 1.33 times.

In irrigated farming, the average high-productivity farm produces 1.84 times what those in low-producing farms do. The highest increase is again with the pearl millet group, which is 3.27 times higher while groundnut again does not respond strongly to high yield scenarios, only increasing at a rate of 1.40 times.

Crop-specific detail is provided in Table 8.

	Production per Acre (Kg.)					
	Rainfed Farming			Irrigated Farming		
	Below Average	Above Average	Increase Compare to Below Average	Below Average	Above Average	Increase Compare to Below Average
Pearl Millet, Maize, Green Gram, Red Gram, Sesamum and Castor	184	523	2.84	391	1277	3.27
Cotton (Lint+Seed)	260	509	1.96	774	1418	1.83
Groundnut (Pod)	627	833	1.33	623	873	1.40
Wheat and Bengal Gram	348	660	1.90	962	1500	1.56

Table 8 : Crop/Crop Groups wise per Acre Production in Low and High Productivity Scenario in Rainfed and Irrigated Farming System

Comparison of GHG Emission – Rainfed Farming

In the case of many of the crops studied, the rainfed farming system often results in decreased emission of CO2 equivalents alongside increased productivity. The survey results show approximately a 41% decrease (per 100 Kg production) in CO2 equivalent emission alongside a 101% increase in production. The groundnut crop in rainfed farming system shows a small increase in emissions corresponding to an increase in production n. Figure 2 provides the detail on these findings.

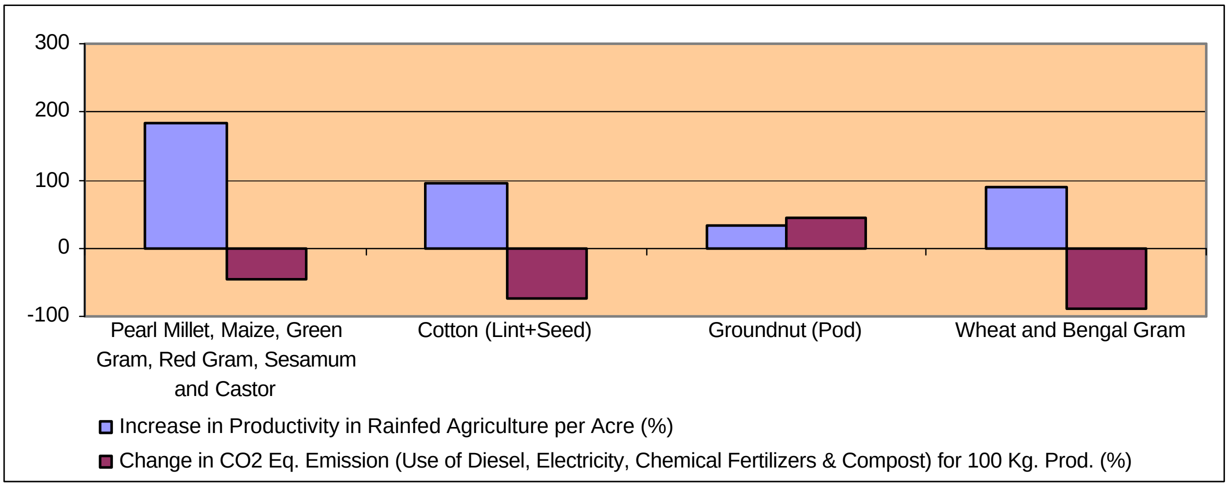


Figure 2 : Comparison of Increase in Productivity and Change in GHG Emission from Low to High Productivity Scenario in Rainfed Farming

Further, when looking at the breakdown of emitting factors, more information can be gleaned as to the reason of the drop in emission production. Many of these reasons result from increased efficiency, which generally lowers resources used. Detail is provided in Figure 3.

- For production of 100 Kg of a crop
  - The largest amount of emission was observed in the low productivity scenario of cotton, at 75 Kg CO2 Eq
  - The lowest was in the high productivity levels of wheat and Bengal gram, at 4 Kg CO2 Eq.

- When productivity is improved upon, per 100 Kg production
    - Emission from Chemical fertilizer use decreases up to 0.26 times
    - Emission from Diesel use decreases up to 0.5 times
    - Emission from compost use increases up to 1.58 times

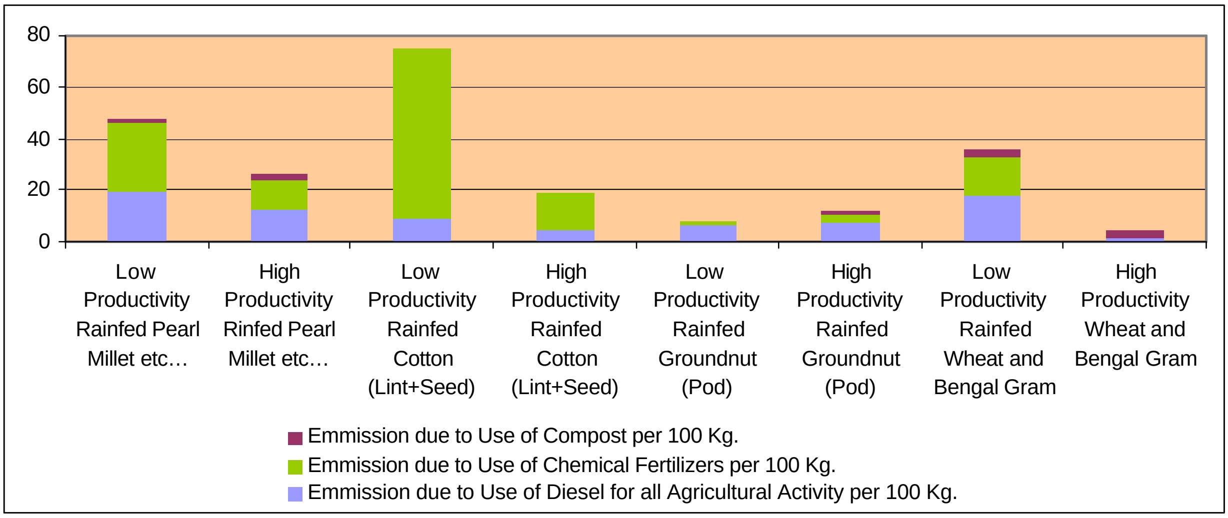


Figure 3 : Comparison of Factors Contributing GHG Emission in Low and High Productivity Scenario in Rainfed Farming

Comparison of GHG Emission and Water Use – Irrigated Farming

GHG Emission

In case of irrigated farming systems, CO2 equivalent emissions increase with the increase in production. In this study, there is close to a 1:1 increase when paired together, as emissions rise 110% when productivity rises 102%. The pearl millet crop group decreases in emission yield with an increased production, whereas cotton and groundnut shows a statistically significant increase in emission. There is a minimal increase in emissions from low to high productivity with wheat and Bengal gram crops. Figure 4 provides the detail.

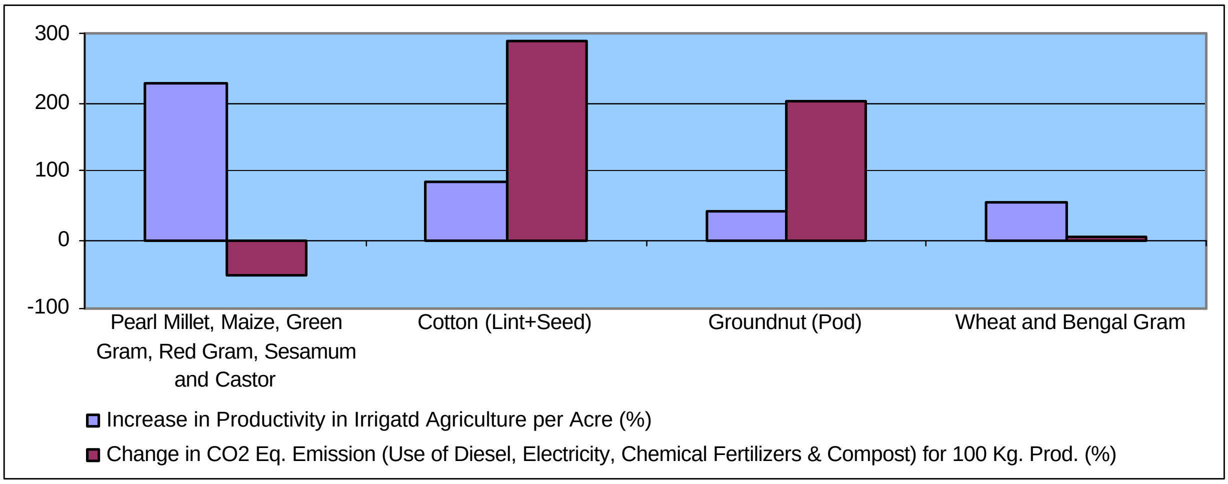


Figure 4 : Comparison of Increase in Productivity and Change in GHG Emission from Low to High Productivity Scenario in Irrigated Farming

In Figure 5, it looks at CO2 emissions under low productivity and high productivity scenarios in irrigated farming.

- For production of 100 Kg
  - The largest amount of emissions results from production of groundnut in the high productivity scenario at a rate of 173 Kg CO2 Eq.
  - The smallest is with a low productivity scheme for cotton, at a rate of 18 Kg CO2 Eq.
- While improving the productivity per 100 Kg production
  - Emission from diesel use decreases by a rate of 0.62 times
  - Emission from compost use increases by a rate of 1.21 times
  - Emission from chemical fertilizer use increases by a rate of 1.24 times
  - Emission due to use of electricity increases by a rate of 1.94 times

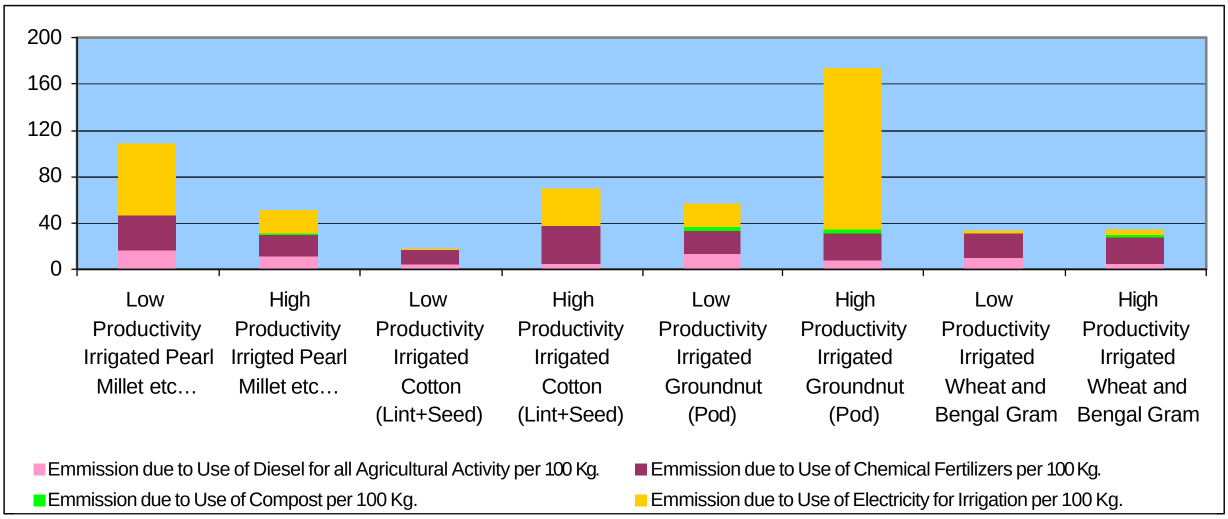


Figure 5 : Comparison of Factors Contributing GHG Emission in Low and High Productivity Scenario in Irrigated Farming

Irrigation Water Use

Changes in water use efficiency has also compared with increase in Productivity with Irrigation Water Use for Different Crops under Irrigated Farming System. Figure 6 provides detail on crop wise water use efficacy for producing 100 Kg. Based on that following can be drawn.

- In irrigated farming
  - to increase 102% productivity, 47 % increase in irrigation water use is observed
  - except Pearl Millet etc.., increase in irrigation water use is observed

- For production of 100 Kg
  - Maximum irrigation water use i.e. 336 CUM observed in low productivity scenario in Pearl Millet etc…
  - Minimum irrigation water use i.e. 66 CUM observed in low productivity scenario in Wheat and Bengal Gram

- While improving the productivity - per 100 Kg production
  - Irrigation water use in Pearl Millet etc.. decrease upto 0.29 times
  - Irrigation water use in Cotton increases upto 1.10 times
  - Irrigation water use in Wheat and Bengal Gram increases upto 2.19 times
  - Irrigation water use in Groundnut increases upto 2.28 times

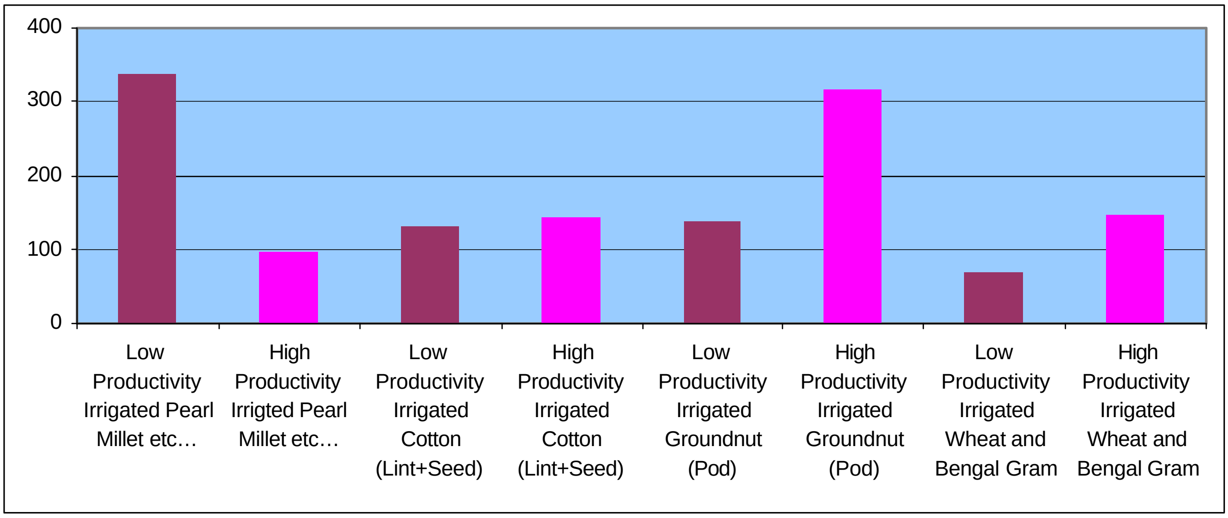


Figure 6 : Comparison of Irrigation Water Use for 100 Kg Production in Low and High Productivity Scenario in Irrigated Farming

Contribution of 1 Kg CO2 Emission in Increasing Productivity

The efficiency of resource use varies widely on rainfed and irrigated farms and in the growth of different crops. This is directly linked with GHG emission and so an attempt was made to determine, for every 1 Kg of greenhouse gas produced, how many additional kilograms of crop is produced. Placing both systems next to each other, all 4 emission-producing inputs, diesel, fertilizers, electricity and compost, were included.

	Contribution of 1 Kg CO2 Equivalents Emission per Acre per Season in Increasing Productivity (Kg.)	
	Rainfed Farming	**Irrigated Farming**
Pearl Millet, Maize, Green Gram, Red Gram, Sesamum and Castor	7.134	3.778
Cotton (Lint+Seed)	Survey suggest that Productivity can be increased with reduced emission	0.747
Groundnut (Pod)	4.346	0.217
Wheat and Bengal Gram	Survey suggest that Productivity can be increased with reduced emission	2.697

Emission from Use of Diesel, Electricity, Chemical Fertilizers and Compost.

Table 9 : Contribution of 1 Kg CO2 Emission per Acre per Season in Increasing Productivity

Table 9 suggests that rainfed farming has a higher return compared to irrigated farming when resources are increased. In the few crops that require more GHG production in order to increase productivity on rainfed farms, the rate of return is higher than those on irrigated farms. Therefore, in this small sample, a small investment in productivity will go further with a smaller environmental impact than an equivalent investment in irrigated farms.

Part – III

Literature Review of Reports Regarding Adaptation of Agricultural Practices for Climate Change and Environmental Sustainability

Agriculture has kept adapting to changing environmental paradigms and the needs of a growing population. Components such as diversification in land use, varied farming systems, crop patterns, agro-biodiversity and associated traditional knowledge and indigenous practices have all played important roles in adjustment to the effects of global climate change. During the modernization of agriculture, monoculture, crop specialization and irrigated farming systems have largely been promoted by government schemes. This has increased the instability of subsistence agriculture in the face of climate change. Increased study needs to be undertaken to enhance adaptation in agriculture for the resultants of climate change and rapid economic and demographic growth.

In this section, a collection of select reports that delve into various methods of agrarian adaptation to climate change were studied and summarized. Largely, the reports describe climate change, its potential impact and suggest ways of mitigating such impact. Specific projections of the impact of climate change are rather limited. In the reports, various adaptation measures are described, but the rationale behind the specific actions, in regards to how it will increase farm resilience and security is not often available.

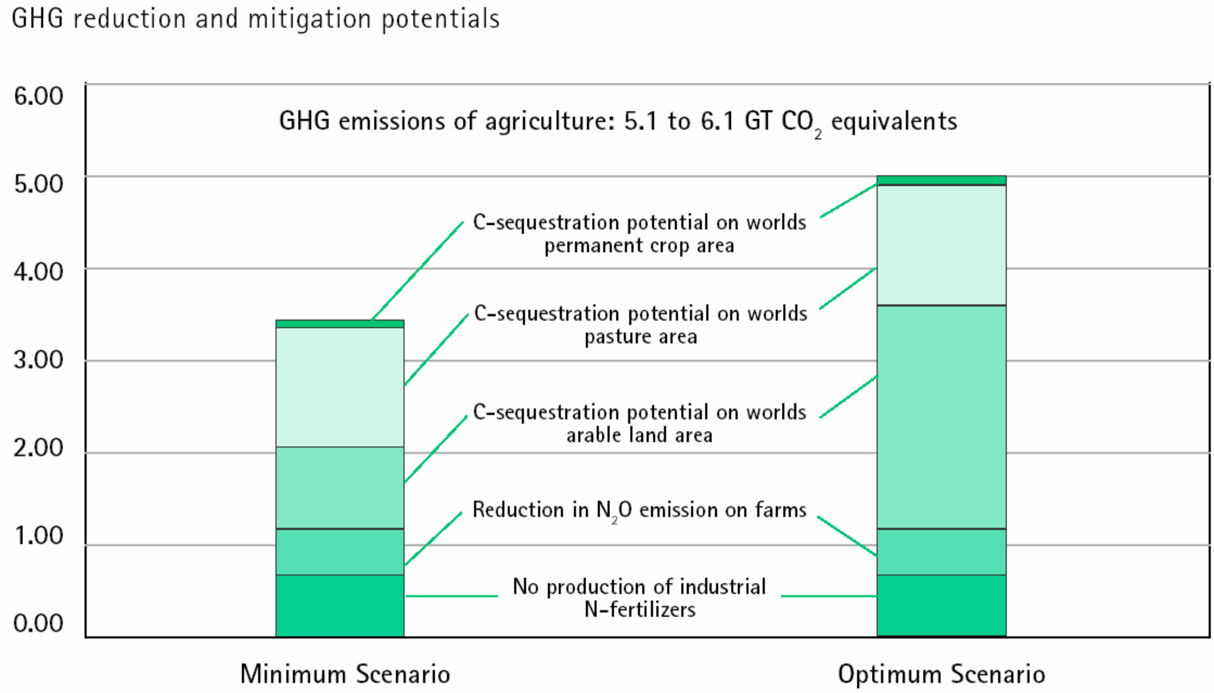
1. Low Greenhouse Gas Agriculture : Mitigation and Adaptation Potential of Sustainable Farming Systems

Published by - FAO
Published in – 2009

Topic Covered

- Climate change mitigation options for agricultural practices and techniques
  - Crop rotations and farming system design
  - Nutrient and manure management
  - Livestock management, pasture and fodder supply improvement
  - Maintaining fertile soils and restoring degraded land
- Is low greenhouse gas emission agriculture possible?
- The potential of ecologically managed farms to adapt to climate change

Important Graph



GHG Reduction and Mitigation Potentials

The GHG emissions of agriculture amounts to 5.1 - 6.1 GT CO2-equivalents. With improved farm and crop management, most of these emissions could be reduced or compensated by sequestration. A conversion to organic agriculture would reduce industrial n-fertilizer use that emits 6.7 kg CO2-eq per kg n on manufacture and another 1.6 percent of the applied n as soil N2O emission. It could also enhance the sequestration of CO2 into the soils in a considerable way. For the minimum scenario, we took a sequestration rate of 200 kg C ha-1 yr-1 for arable and permanent crops and 100 kg C ha-1 yr-1 for pastures. The optimum scenario combines organic farming with reduced tillage on arable land (sequestration rate 500 kg C ha-1 yr-1).

Highlight of the Report

- Provides account of potential nitrogen production by leguminous plants and emission from livestock waste
- Compares different farming systems in the context of carbon sequestration
- Through calculation, suggests that the carbon sequestration in arable and pasture land, under ideal circumstances, can offset the GHG emission from agriculture

2. Organic Farming and Climate Change

Published by - Research Institute of Organic Agriculture (FiBL)
Published in – 2007

Topics Covered

- Agriculture as Cause and Victim of Climate Change
- The Potential of Organic Farming to Mitigate Climate Change
- Does Organic Farming have Greater Potential to Adapt to Climate Change?
- What are the Weaknesses of Organic Agriculture in the Context of Climate Change?
- Climate credit for organic farming?

Important Graph and Detail

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Relative global warming potential of organic agriculture compared to conventional agriculture (basis: grams CO2 equivalents per kg product). At the experiment and farm level, all crops in a rotation were compared.

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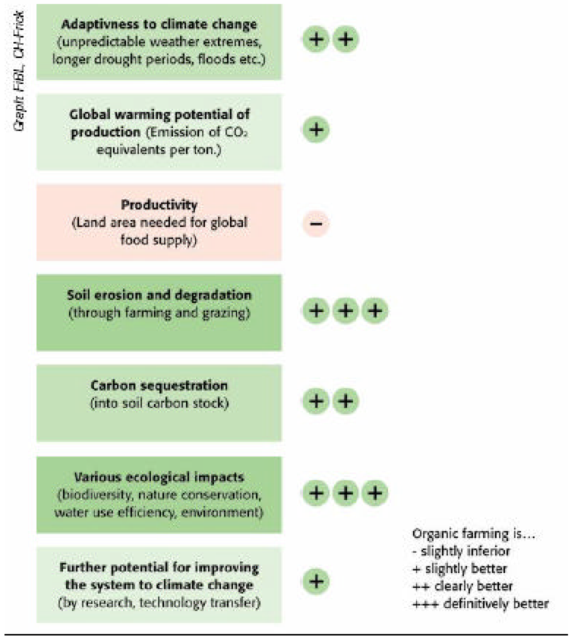

Performance of organic agriculture compared to conventional agriculture in the context of climate change.

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</table>

<table>
<tr><th colspan="2">Potential of Organic Farming for Adaptation to Climate Change</th></tr>
<tr>
<td>Traditional skills and knowledge as a key to adaptation to climate change</td>
<td>Traditional skills and knowledge have been neglected in intensive agriculture, although they are now being partially recaptured by integrated pest management. Organic agriculture, on the other hand, has always been based on practical farming skills, observation, personal experience and intuition. Knowledge and experience replaces or reduces reliance on inputs. This knowledge is important for manipulating complex agro-ecosystems, for breeding locally adjusted seeds and livestock, and for producing on-farm fertilizers (compost, manure, green manure) and inexpensive nature-derived pesticides. Such knowledge has also been described as a ‘reservoir of adaptations’ (Tengo and Belfrages, 2004).</td>
</tr>
<tr>
<td>Organically managed soils are better adapted to weather extremes</td>
<td>Farming practices such as organic agriculture that preserve soil fertility and maintain or even increase organic matter in soils are in a good position to maintain productivity in the event of drought, irregular rainfall events with floods, and rising temperatures. Soils under organic management retain significantly more rainwater thanks to the ‘sponge properties’ of organic matter.

These ‘sponge properties’ were described for heavy loamy soils in a temperate climate in Switzerland where soil structure stability was 20–40% higher in organically managed soils than in conventional soils (Mäder et al., 2002).
The amount of water percolating through the top 36 cm was 15–20% greater in the organic systems of the Rodale farming systems trial compared to conventional systems. The organic soils held 816,000 litres per ha in the upper 15 cm of soil. This water reservoir was likely the reason for higher yields of corn and soybean in dry years (Pimentel et al., 2005).
It was found that water capture in organic plots was twice as high as in conventional plots during torrential rains (Lotter et al. (2003). This significantly reduced the risk of floods, an effect that could be very important if organic agriculture were practised on much larger areas.

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Enhancing productivity of degraded soils by building soil fertility	Experience with degraded soils of the arid tropics have shown that agricultural productivity can be enhanced using soil fertility building techniques. In the Tigray province of Ethiopia, one of the most degraded parts of the country, agricultural productivity was enhanced by soil fertility techniques such as compost application and introduction of leguminous plants into the crop sequence. By restoring soil fertility, yields were increased to a much greater extent both at farm and regional level than by using bought mineral fertilizers (Edwards, 2007). This large-scale experiment underlines the importance of organic matter and soil fertility for ensuring productivity in dry regions and partly explains the surprisingly high yields from organic crops found by Badgley et al. (2007).
Diversity enhances farm resilience	An additional strength of organic farming systems is their diversity – including the diversity of crops, fields, rotations, landscapes and farm activities (mix of various farm enterprises). The high level of diversity of organic farms provides many ecological services that significantly enhance farm resilience (Bengtsson et al., 2005; Hole et al., 2005). Positive effects of enhanced biodiversity on pest prevention have been shown by several authors (Zehnder et al., 2007; Wyss et al., 2005; Pfiffner et al., 2003). Similar effects of diversified agro-ecosystems on diseases and better utilization of soil nutrients and water are likely to occur (Altieri et al., 2005).

Highlight of the Report

- Makes an attempt to simplify the scientific understanding of organic cultivation in context of climate change
- Gives detailed account of carbon sequestration
- Provides basic scientific understanding on the role organic methods of soil management plays in enhancing adaptation to weather extremes

3. "Climate-Smart" Agriculture Policies, Practices and Financing for Food Security, Adaptation and Mitigation

Published by – FAO
Published in – 2010

Topic Covered

- Examples of climate smart production systems
- Institutional and policy options
- Financing and investments for climate smart agriculture

Important Detail

Components Enhances Efficiency, Resilience, Adaptive Capacity and Mitigation Potential	
Soil and nutrient management	▪ Emphasizing on increasing organic nutrient inputs and legumes
Water harvesting and use	▪ Emphasizing on improved water harvesting, retention and use
Pest and disease control	▪
Resilient ecosystem	▪ Emphasizing on improving management for better ecosystem services
Genetic resources	▪ Emphasizing on generating varieties and breeds which are tailored to ecosystems and the needs of farmers.
Harvesting, processing and supply chains	▪ Emphasizing on reducing post harvest losses, increase in operational efficiency, better use of co-products and by-products, storage of surplus for low production years
Conservation Agriculture	▪ Minimal mechanical soil disturbance (i.e. no tillage and direct seeding) ▪ Maintenance of a mulch of carbon- rich organic matter covering and feeding the soil (e.g. straw and/or other crop residues including cover crops); and ▪ Rotations or sequences and associations of crops including trees which could include nitrogen- fixing legumes

Livestock production efficiency and resilience	▪ Application of science and advanced technology in feeding and nutrition, genetics and reproduction, and animal health control as well as general improvements in animal husbandry ▪ Improved forecasting of risks, determination of the effects of climate change, early detection and control of disease outbreaks are also fundamental to allow prompt responses and build resilience
Agroforestry	▪ Trees and shrubs can diminish the effects of extreme weather events, such as heavy rains, droughts and wind storms. ▪ They prevent erosion, stabilize soils, raise infiltration rates and halt land degradation. ▪ They can enrich biodiversity in the landscape and increase ecosystem stability.
Strengthen urban and peri-urban agriculture	▪
Strengthen diversified and integrated food – energy systems	▪ Developing production systems which also meet the energy requirements of smallholders is also important.

Highlight of the Report

- Effective climate-smart practices already exist and could be implemented in developing country agricultural systems.
- Adopting an ecosystem approach, working at landscape scale and ensuring inter-sectoral coordination and cooperation is crucial for effective climate change responses.
- Considerable investment is required in filling data and knowledge gaps and in research and development of technologies, methodologies, as well as the conservation and production of suitable varieties and breeds.

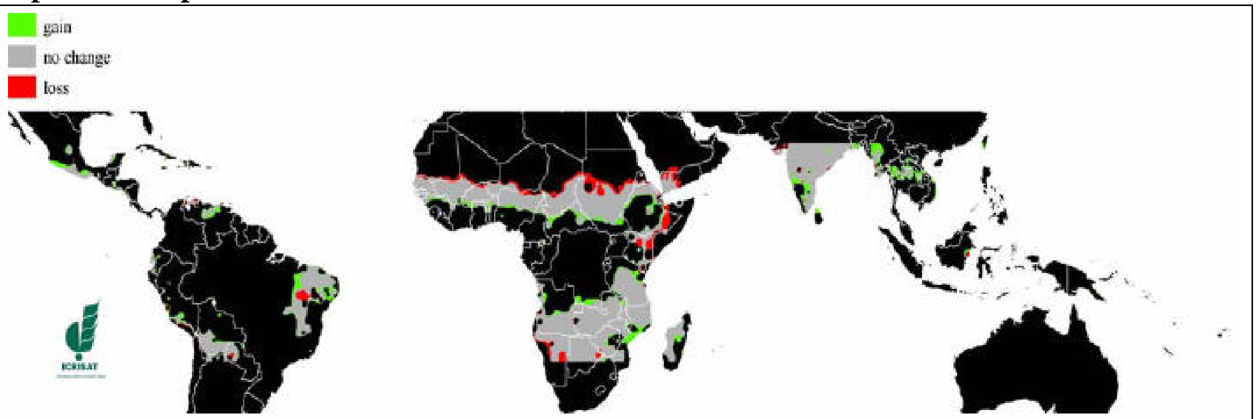
4. Farming with Current and Future Climate Risk : Advancing a 'Hypothesis of Hope' for Rainfed Agriculture in Semi-arid Tropics

Author - P. Cooper et. al., Scientist, ICRISAT
Published in – 2009

Topic Covered

- Impacts of climate change on Length of Growing Period (LGP)
- Impacts of climate change on distribution of Semi-arid Tropics
- The impact of climate change on the crop growth and yield
- Mitigating the impacts of climate change through natural resources management and crop adaptation

Important Map



The projected change in the global extent of the SAT resulting from a mean temperature increase of 2dC and an average decline of 10% rainfall.

Highlight of the Report

- Works towards figuring out extent of impact of climate change on distribution of Semi-Arid Tropics (SAT)
- Attempts to figure out impact of climate change on:
    - Different cultivars of the same crops, such as short duration and medium duration cultivars
    - The productivity of the same crop grown in different areas
    - Same crop growth rates with different level of inputs
- One suggested adaptation measure is improved practice with adapted germplasm

5. Rediscovery of Traditional Ecological Knowledge as Adaptive Management

Author - Fikretb Erke (University of Manitoba), Johan Colding (Stockholm University) and Carlf Olke (Stockholm University)
Published in – 2000

Topic Covered

- Practices based on traditional ecological knowledge
- Social mechanisms behind traditional practices
- Qualitative approaches for adaptive management

Important Table

Social-Ecological Practices and Mechanisms in Traditional Knowledge and Practice (adapted from Folke et al. 1998). Management Practices based on Ecological Knowledge		
Practices found both in conventional resource management and in some local and traditional societies	Practices largely abandoned by conventional resource management but still found in some local and traditional societies	Practices related to the dynamics of complex systems, seldom found in conventional resource management but found in some traditional societies
▪ Monitoring resource abundance and change in ecosystems ▪ Total protection of certain species ▪ Protection of vulnerable life history stages ▪ Protection of specific habitats ▪ Temporal restrictions of harvest	▪ Multiple species management: maintaining ecosystem structure and function ▪ Resource rotation ▪ Succession management	▪ Management of landscape patchiness ▪ Watershed-based management ▪ Managing ecological processes at multiple scales ▪ Responding to and managing pulses and surprises ▪ Nurturing sources of ecosystem renewal

Highlight of the Report

- Author has studied international literature to focus on the role of Traditional Ecological Knowledge in monitoring, responding to, and managing ecosystem processes and functions, with special attention to ecological resilience.
- Provides understanding on
    - Practices found both in conventional resource management and in some traditional societies
    - Practices largely abandoned by conventional resource management but still found in some local and traditional societies

- o Practices related to the dynamics of complex systems seldom found in conventional resource management
- Author suggests that traditional systems had certain similarities to adaptive management with its emphasis on feedback learning, and its treatment of uncertainty and unpredictability intrinsic to all ecosystems.

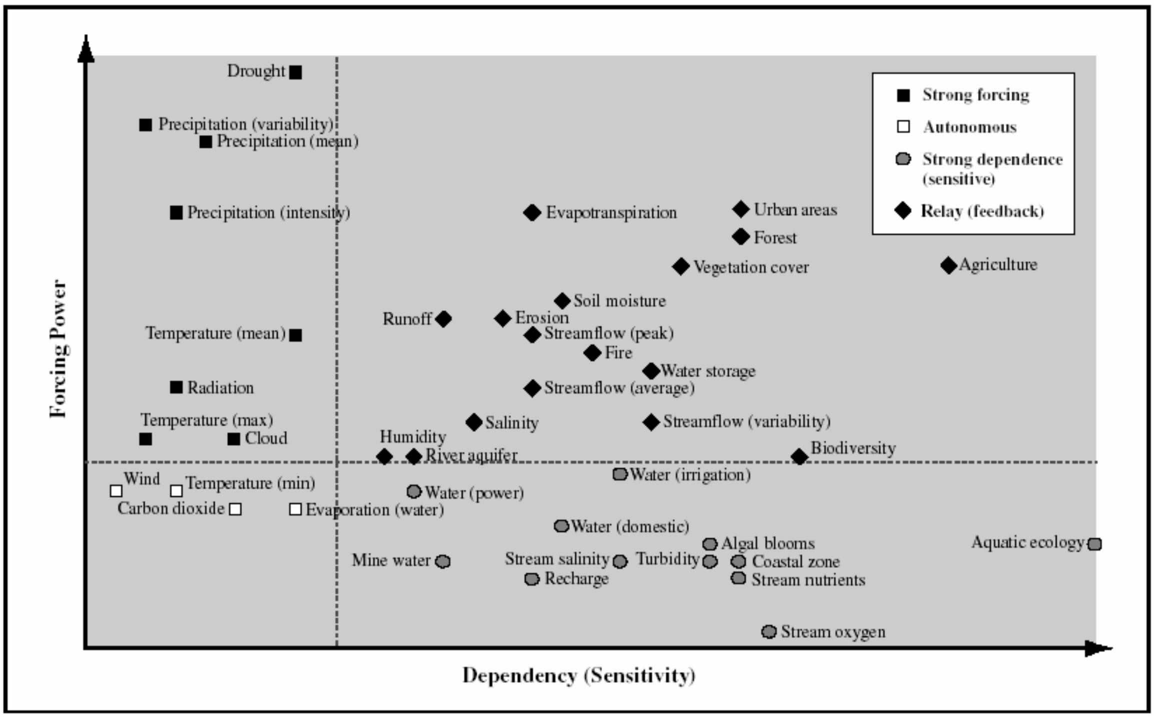
6. Adaptation Policy Frameworks for Climate Change : Developing Strategies, Policies and Measures

Prepared by - UNDP and Cambridge University
Published in - 2004

Topic Covered

- Scoping and Designing an Adaptation Project
- Engaging Stakeholders in the Adaptation Process
- Assessing Vulnerability for Climate Adaptation
- Assessing Current Climate Risks
- Assessing Future Climate Risks
- Assessing Current and Changing Socio-Economic Conditions
- Assessing and Enhancing Adaptive Capacity
- Formulating an Adaptation Strategy
- Continuing the Adaptation Process

Important Graph



Forcing/dependency chart for climate, catchment processes and catchment-based activities in the Hunter River Valley (based on the cross-impacts analysis)

Highlight of the Report

- Provides theoretical framework for adaptation
- Provides various tools for analysis
- Provides understanding on relationship between forcing power and dependency/sensitivity
- Emphasize on adaptive capacity

Annexure I

Assessment of Diesel Consumption and Computation of Green House Gas Emission

Method for Assessment of Diesel Consumption

Diesel usage in agriculture stems from many activities. These include the following: transportation of fertilizer and compost, plowing, sowing, inter-cultivation, irrigation, harvesting, transportation up to threshing yard, threshing and transportation for market. During the survey for various activities, information was collected in the following manner and later, activity-specific data and total diesel consumption data was computed.

Activity	Implement Used	Capacity in Hp	Usage	Efficiency	No. of Operations	Diesel Use in Lit
Transportation of Fertilizer and Compost	Vehicle used		Total KM Run	Efficiency KM/Lit		Diesel Used Lit
Plowing	Type of Implement		Hours Used per Operation	Efficiency Lit/Hr	No of operations	Diesel Used Lit
Sowing	Type of Implement		Total Hours Used	Efficiency Lit/Hr		Diesel Used Lit
Inter-cultivation	Type of Implement		Hours Used per Operation	Efficiency Lit/Hr	No of operations	Diesel Used Lit
Irrigation	Type of Device		Hours Used per Irrigation	Efficiency Lit/Hr	No. of Irrigation	Diesel Used Lit
Harvesting	Method of Harvesting		Total Hours Used	Efficiency Lit/Hr		Diesel Used Lit
Transportation up to Threshing Yard	Vehicle used		Total KM Run	Efficiency KM/Lit		Diesel Used Lit
Threshing	Threshing Device		Total Hours Used	Efficiency Lit/Hr		Diesel Used Lit
Transportation for Market	Vehicle used		Total KM Run	Efficiency KM/Lit		Diesel Used Lit
Total Diesel Consumption in Lit per Season						

Analysis of Diesel Consumption

	Diesel Consumption per Acre per Season (Lit)			Diesel Consumption per 100 Kg. Production (Lit)		
	Rainfed Farming	Irrigated Farming	Increase Compare to Rainfed Farming/Mango	Rainfed Farming	Irrigated Farming	Increase Compare to Rainfed Farming/Mango
Pearl Millet, Maize, Green Gram, Red Gram, Sesamum and Castor	19.44	100.00	5.14	5.56	13.06	2.35
Cotton (Lint+Seed)	8.69	26.78	3.08	2.27	2.60	1.15
Groundnut (Pod)	20.10	33.90	1.69	2.74	4.81	1.76
Wheat and Bengal Gram	18.60	44.20	2.38	4.42	3.60	0.81
Average	16.71	51.22	3.07	3.75	6.02	1.61

Mango		1.01			0.04	
Sapota		13.14	13.01		0.25	6.25
Banana		31.97	31.65		0.10	2.50

From the above table, the following information can be drawn.

- Per acre diesel consumption for seasonal and annual crops:
  - In rainfed agriculture, the average is 16 Lit
  - In irrigated agriculture, the average is 51 Lit
  - In irrigated agriculture per acre diesel consumption is 3.07 times higher than the rainfed agriculture

- Per 100 Kg production diesel consumption for seasonal and annual crops:
  - In rainfed agriculture, the average is 3.75 Lit
  - In irrigated agriculture, the average is 6.02 Lit
  - In irigated agriculture per 100 Kg production diesel consumption is1.61 times higher than the rainfed agriculture

- In Horticulture
  - per acre banana cultivation is 31.65 times higher than the mango cultivation
  - per 100 Kg banana production is 2.50 times higher than the mango production

Computation of Green House Gas Emission

For computation of green house gas emission from diesel and the conversion into CO2 equivalent, the following calculation was used. This method is proposed in IPCC Guidelines, Ch. 2, Vol. 2, 2006.

Emitting Gas	Fuel Consumption in Energy Units TJ	EFs for Agricultural Operations Kg./TJ	Emission Kg.	Factor to Convert into CO2 Eq. Kg.	CO2 Eq. Kg.	Total CO2 Eq. Kg. Emission form 1 Lit Diesel
CO2	35.7 x10-6	74100	2.64	1	2.64	2.648797
CH4	35.7 x10-6	3	0.0001071	23	0.002463	
N2O	35.7 x10-6	0.6	0.0000214	296	0.006334	

Calculation detail for fuel consumption in energy units (TJ – tera joule)

Fuel Consumption in Energy Units TJ = **Fuel Consumption in Mass/Volume units** X **Net Calorific Value (NCV) of Diesel** X **10-6**

Where
- 1 Lit Diesel = 0.83 Kg.
- Net Calorific Value (NCV) of Diesel = 43 MJ/Kg.
- 1 Mega Joule = 10-6 Tera Joule

Annexure II

Assessment of Chemical Fertilizer Application and Computation of Green House Gas Emission

Method for Assessment of Chemical Fertilizer Application

As natural nitrogen reserves in soil is depleted, chemical fertilizers are mainly used to provide nitrogen to plant. The survey asked for information on the following three questions.

Name of Fertilizers	Total no. of Begs Applied in a Season	Total Quantity of Chemical Fertilizer applied in Kg

Analysis of Chemical Fertilizer Application

	Chemical Fertilizer Application per Acre per Season (Kg.)			Chemical Fertilizer Application per 100 Kg. Production (Kg.)		
	Rainfed Farming	Irrigated Farming	Increase Compare to Rainfed Farming/Mango	Rainfed Farming	Irrigated Farming	Increase Compare to Rainfed Farming/Mango
Pearl Millet, Maize, Green Gram, Red Gram, Sesamum and Castor	47.14	115.34	2.45	7.76	11.10	1.43
Cotton (Lint+Seed)	91.67	213.05	2.32	14.35	12.91	0.90
Groundnut (Pod)	96.88	111.40	1.15	1.68	15.22	9.06
Wheat and Bengal Gram	18.15	125.66	6.92	3.31	10.07	3.04
Average	63.46	141.36	2.23	6.78	12.33	1.82
Mango		360.00			1.45	
Sapota		108.15	0.30		1.32	0.91
Banana		1105.26	3.07		3.50	2.41

The above table shows that:

- Per acre chemical fertilizer application for seasonal and annual crops:
  - In rainfed agriculture, the usage is 63 Kg
  - In irrigated agriculture, the usage is 141 Kg
  - In irrigated agriculture, per acre chemical fertilizer application is 2.23 times higher than the rainfed agriculture

- Per 100 Kg production chemical fertilizer application for seasonal and annual crops
  - In rainfed agriculture, the usage is 6.78 Kg
  - In irrigated agriculture, the usage is 12.33 Kg
  - In irigated agriculture per 100 Kg of crop production, chemical fertilizer application is 1.82 times higher than the rainfed agriculture

- In Horticulture
  - per acre banana cultivation is 3.07 times higher than the mango cultivation
  - per 100 Kg banana production is 2.41 times higher than the mango production

Computation of Green House Gas Emission

Application of chemical fertilizer emits N2O from nitrogenous fertilizer and CO2 from urea. For computation of green house gas emission from chemical fertilizer application and the subsequent conversion into CO2 equivalent, the following calculation was used. This method is suggested in the IPCC Guidelines, Ch. 11, Vol. 4. While calculating emission values, GHG resulting in the off-site production of chemical fertilizers is not taken into account.

N2O Emission from Nitrogenous Fertilizer

Emission in CO2 Eq. Kg. due to Application of N Chemical Fertilizers	**=**	**Total N Applied in Kg in Chemical Fertilizer**	**X**	**Emission Factor**	**X**	**Conversion of N into N2O**	**X**	**Factor to Convert N2O into CO2 Eq. Kg.**

Where

- Total applied N in Kg in chemical fertilizers was derived from quantity of chemical fertilizers used in 1 Kg multiplied by nitrogen content in the chemical fertilizers
- Nitrogen content in various chemical fertilizers were found at www.gsfclimited.com and https://www.gnfc.in

Name of Nitrogenous Fertilizer	% N Content
Urea	46.2
Ammonium Sulphat	20.6
Di-Ammonium Phosphate (DAP)	18
Calcium-Ammonium Nitrate (CAN)	25
Ammonium Nitrophosphate	20
NPK 12:32:16	12

- Emission factor = 0.01
- Conversion of N into N2O = 44/28
- Factor to conversion of N2O into CO2 equivalent is 296

CO2 Emission from Urea

Emission in CO2 Eq. Kg. due to Application of Urea	**=**	**Application of Urea in Kg**	**X**	**Emission Factor**	**X**	**Conversion of C into CO2**

Where

- Quantity of application of Urea derived from survey data
- Emission factor = 0.2
- Conversion of C into CO2 = 44/12

Annexure III

Assessment of Electricity Consumption and Computation of Green House Gas Emission

Method for Assessment of Electricity Consumption

In agriculture, electricity is mainly consumed during the lifting of water from a well or bore well for irrigation. During the survey, information on irrigation was collected in following manner and later, total electricity consumption was computed.

Type of Lifting Device	Capacity in HP	No. of Irrigation	Hour Used per Irrigation	Total Hour Used

Total Electricity Consumed in KWHr - Unit = Capacity of Pumping Device (HP) X Total Hours Used X 0.746

Analysis of Electricity Consumption

	Electricity Consumption for Irrigation per Acre per Season (KWHr - Unit)			Electricity Consumption for Irrigation per 100 Kg. Production (KWHr - Unit)		
	Rainfed Farming	Irrigated Farming	Increase Compare to Pearl Millet etc/Mango	Rainfed Farming	Irrigated Farming	Increase Compare to Pearl Millet etc/Mango
Pearl Millet, Maize, Green Gram, Red Gram, Sesamum and Castor	-	508.62		-	53.67	
Cotton (Lint+Seed)	-	501.32	0.99	-	36.03	0.67
Groundnut (Pod)	-	1214.64	2.39	-	147.87	2.76
Wheat and Bengal Gram	-	149.42	0.29	-	11.47	0.21
Average		593.50			62.26	
Mango	-	275.60		-	10.00	
Sapota	-	1315.56	4.77	-	23.97	2.40
Banana	-	1698.16	6.16	-	5.38	0.54

From the above table following can be drawn.

- Rainfed farming does not require electricity consumption
- Per acre Electricity consumption for seasonal and annual crops
  - In irrigated agriculture, the average usage is 593.50 kilowatt per hour.
  - In irrigated agriculture per acre, electricity consumption is highest for groundnut cultivation and is 2.39 times higher than the pearl millet group
- Per 100 Kg production Electricity consumption for seasonal and annual crops
  - In irrigated agriculture is 62 Kw/hr
  - In irrigated agriculture per 100 Kg production, groundnut production still requires, by far, the most amount of irrigation and therefore electricity use.
- In Horticulture
  - per acre Banana cultivation is 6.16 times higher than the mango cultivation
  - per 100 Kg Banana production is 0.54 compare to mango production

Computation of Green House Gas Emission

For computation of green house gas emission from electricity and conversion into CO_2 equivalent, following calculation was used. This method is proposed in CO_2 Baseline Database for the Indian Power Sector, User Guide, Version 2.0, June 2007.

Emission in CO2 Eq. Kg.	**=**	**Total electricity consumed in KWH**	**X**	**0.88**

Annexure IV

Assessment of Compost Application and Computation of Green House Gas Emission

Method for Assessment of Compost Application

In agriculture compost, farm yard manure (FYM) and de-oiled cakes are used to provide various nutrients and to build up soil carbon. During research, information on total quantity of compost, including FYM and de-oiled cakes applied for that season, was collected and computed into MT.

Analysis of Compost Application

	Compost Application per Acre per Season (MT)			Compost Application per 100 Kg. Production (MT)		
	Rainfed Farming	Irrigated Farming	Increase Compare to Rainfed Farming/Mango	Rainfed Farming	Irrigated Farming	Increase Compare to Rainfed Farming/Mango
Pearl Millet, Maize, Green Gram, Red Gram, Sesamum and Castor	3.697	5.063	1.37	0.402	0.219	0.54
Cotton (Lint+Seed)	2.500	5.478	2.19	0.065	0.129	1.98
Groundnut (Pod)	1.970	4.100	2.08	0.141	0.560	3.97
Wheat and Bengal Gram	3.601	7.775	2.16	0.786	0.518	0.66
Average	2.942	5.604	1.90	0.349	0.357	1.02
Mango		1.422			0.052	
Sapota		2.500	1.76		0.030	0.58
Banana		17.105	12.03		0.054	1.04

From the above table, the following information can be gleaned:

- Per acre compost application for seasonal and annual crops
    - In rainfed agriculture, the average usage is 2.9 MT
    - In irrigated agriculture, the average usage is 5.6 MT
    - In irrigated agriculture per acre compost application is 1.90 times higher than rainfed farms

- Per 100 Kg production compost application for seasonal and annual crops
    - In rainfed agriculture, the average amount used is 349 Kg
    - In irrigated agriculture, the average amount used is 357 Kg
    - In irigated agriculture per 100 Kg production compost application is 1.02 times higher than the rainfed agriculture

- In Horticulture
    - per acre banana cultivation is 12.03 times higher than the mango cultivation
    - per 100 Kg banana production is 1.04 times higher than the mango production

Computation of Green House Gas Emission

Application of compost, FYM and de-oiled cakes into soil helps building soil carbon. However at the same time, application of compost, FYM and de-oiled cakes emits N2O. For computation of green house gas emission from compost, FYM and de-oiled cakes application and their conversion into CO2 equivalent, the following calculation was used. This method is proposed in IPCC Guidelines, Ch. 11, Vol. 4. While calculating emissions, the value of carbon sequestration, which is quite high, is not taken into account.

N2O Emission from Compost

Emission in CO2 Eq. Kg. due to Application of Compost	**=**	**Total N Applied in Kg from Compost**	**X**	**Emission Factor**	**X**	**Conversion of N into N2O**	**X**	**Factor to Convert N2O into CO2 Eq. Kg.**

Where

- Total applied N in Kg in compost, FYM and de-oiled cakes is derived from the quantity of compost, FYM and de-oiled cakes used in 1 Kg multiplied by nitrogen content in the compost, FYM and de-oiled cakes.
- Nitrogen content in various compost, FYM and de-oiled cakes data comes from the Handbook Agriculture, ICAR, 2009

Name	% N Content
Compost/FYM/Manure	0.01
Neem Cake	0.055
Castor Cake	0.052
Cow Urine/Jivamrut	0.009

- Emission factor = 0.001
- Conversion of N into N2O = 44/28
- Factor to conversion of N2O into CO2 equivalent is 296

Annexure V

Assessment of Irrigation Water Use

Method for Assessment of Irrigation Water Use

Applying water in excess to rainfall divides the farming operations into rainfed farming and irrigated farming. In agriculture, irrigation is an important component to increase productivity. In the research period, various factors of irrigation were collected under the following headings and, later, total irrigation water use was computed in Cubic Meter (CUM).

Type of Source	Irrigation Method	Type of Pumping Device	Capacity in HP	Diameter of suction pipe in Inch	Length of suction pipe in Mt.	Diameter of delivery pipe in Inch	Head/ Length of delivery pipe in Mt.	No. of Irrigation	Hour Used per Irrigation	Total Hour Used

Based on the filled-out surveys, estimates of the total hours of pumping during a particular season and year was computed. Further information based on the capacity of the pumping device, for example, the discharge capacity of specific lifting and the total volume of irrigation water use has calculated. This approach of mathematical synthesis was used where farmers are applying irrigation water through flooding. In cases where farmers have used drip irrigation, case-specific calculations were made.

During the survey, it was found that farmers use diesel engine or mono-block electrical motor and submersible pumping devises. Discharge capacities in Liter per Minute (LPM) for these devices were drawn from the following tables.

Discharge Computation for Diesel Engine/Mono-block Electric Motor

To compute the discharge in Liter per Minute (LPM) from Diesel Engine/Mono-block Electric Motor, the following table was used. This table is proposed in Studies on Water Resource Development and Management of Pachchham Island : A Case Study of Kachchh by Dr. Y J Jadeja, 2005

Type of Pump	Capacity HP	Discharge LPM
Diesel Engine	5	250
	8	300
	10	340
	>12	425
Mono-block	10	3720

Discharge Computation for Submersible Pump

To compute the discharge in Liter per Minute (LPM) from submersible pumps, the following tables were used. These tables are proposed by Lubi (a pump set manufacturer, whose pump set are popular in Gujarat).

Capacity of Submersible Pump in HP	Discharge (LPM) (for Outlet size 75 mm(3”) n=2880					Discharge (LPM) (for Outlet size 100 mm(4”) n=2880				
	450	500	600	700	850	650	800	950	1050	1200
	Heads in Meter					Heads in Meter				
7.5		38	36		26					
10	56	54	50	45	33	38	36	32	30	24
12.5	74	72	66	60	44					
15	93	90	83	75	55	57	54	48	4	36
17.5	111	108	99	90	66					
20	130	126	116	105	77	76	72	64	60	48
25	148	144	132	120	88	95	90	80	75	50
30	185	180	165	150	110	114	108	95	90	72
35	222	216	198	180	132	133	126	112	105	84
40		190	180		130	152	144	128	120	96
45						171	162	144	135	108
50		228	216		156	190	180	160	150	120
55						209	198	176	165	132
60						228	216	192	180	144

Analysis of Irrigation Water Use

	Irrigation Water Use per Acre per Season (CUM)			Irrigation Water Use per 100 Kg. Production (CUM)		
	Rainfed Farming	Irrigated Farming	Increase Compare to Pearl Millet etc/Mango	Rainfed Farming	Irrigated Farming	Increase Compare to Pearl Millet etc/Mango
Pearl Millet, Maize, Green Gram, Red Gram, Sesamum and Castor	-	1285.31		-	182.47	
Cotton (Lint+Seed)	-	1786.60	1.39	-	141.24	0.77
Groundnut (Pod)	-	1697.04	1.32	-	231.84	1.27
Wheat and Bengal Gram	-	1465.66	1.14	-	117.46	0.64
Average		1558.65			168.25	
Mango	-	701.16		-	25.45	
Sapota	-	3734.52	5.33	-	68.11	2.68
Banana	-	42972.63	61.29	-	136.08	5.35

- Rainfed farming does not require irrigation water use

- Per acre water use for seasonal and annual crops
  - In irrigated agriculture, water use is 1558 CUM
  - In irrigated agriculture per acre water use for cotton cultivation is the highest, about 1.32 times higher than the pearl millet group.

- Per 100 Kg production water use for seasonal and annual crops
  - In irrigated agriculture, water use is 168 CUM
  - In irrigated agriculture per 100 Kg water use for groundnut cultivation is highest, while cotton ends up have the lowest rate of use per Kg.

- In Horticulture
  - per acre banana cultivation is 61.29 times higher than the mango cultivation
  - per 100 Kg banana production is 5.35 times higher than the mango production

Survey Form

Format for Study to Compare Energy Efficiency, Soil Fertility and Water Use in Various Farming System

Part – A : Primary Information

1. Name of Village: _________________Taluka:_______________District:____________ _______
2. Average annual rainfall of area: ___________ Rainfall of last year:______________
3. Name of farmer:__________________________________. No. of family members:____ .
4. Contact number of information provider: ___________________
5. No. of Animals:

Cow		Buffalo		Bullock		Sheep-Goat		Camel		Horse	

6. Do you have Bio-Gas? Yes _______ No ______ .
   If Yes, Is it in working condition? ______ Or, it defunct?______ .
   If, Bio-Gas is working condition, what is its capacity? _________________
   For how many days in a year, you are using Bio-Gas? _________________.

Part – B : Farm and Crop Detail

Total Area [ ] Acre

Name of piece of land under study [ ] Area in Acre [ ]

Soil Type v Tick any
Light [ ] Medium [ ] Heavy [ ]

Type of Farming v Tick any
Rainfed [ ] Irrigated [ ]

1. Detail of Crop Sown during Last Year

Type of Farming		Summer, Year 2009		Kharif, Year 2009-10		Rabi, Year 2009-10	
		Name	Area in Acre	Name	Area in Acre	Name	Area in Acre
Rainfed	Primary Crop						
	Secondary Crop						
Irrigated	Primary Crop						
	Secondary Crop						

2. Crop Production

Season	**Crop**	**Objective of the crop grown**	**Production in Kg.**	**Sell in Kg.**	**Sell Price Rs. / Kg.**	**Fodder production Kg.**
Summer, Year 2009	1.					
	2.					
	3.					
	4.					
Kharif, Year 2009-10	1.					
	2.					
	3.					
	4.					
Rabi, Year 2009-10	1.					
	2.					
	3.					
	4.					

Note: *Consider following options for Objective*

1. Only for Home Consumption, 2. Only for Market, 3. Home Consumption + Market

Part – C : Detail of Irrigation Method

1. Type of Source:

Well		Bore well		Canal		Dam/Talab		Other	

Please v according to pump device and Irrigation Method	Flood Irrigation			Sprinkler Irrigation			Drip Irrigation		
	S	K	R	S	K	R	S	K	R
Gravity Flow (Through Canal)									
Diesel Engine									
Electric Motor – Monoblock									
Electric Motor - Submarsible									

2. Detail of Water Lifting :

Total depth of well/bore ______________mt.

Diameter of bore : __________________ inch

Water level in bore/well : __________mt.

Type of pumping device : _______________.

Capacity of pumping device :_______hp

Diameter of suction pipe : ____________inch

Diameter of delivery pipe : ________inch

Length of suction pipe : _______________mt

Length of delivery pipe : __________mt

3. No. of Irrigation :

Sr. No.	Summer, Year 2009		Kharif, Year 2009-10		Rabi, Year 2009-10	
	Crop	No. of Irrigation	Crop	No. of Irrigation	Crop	No. of Irrigation
1						
2						
3						

4. Assessment of water used for Irrigation (for study area only)

a. To provide one irrigation by flood irrigation system, for how many hours pumping device needs to be run ? ___________hr

b. Provide below detail for the Sprinkler and Drip Irrigation

Sprinkler Irrigation		Drip Irrigation	
Capacity of one sprinkler		Capacity of one lateral	
No. of total sprinklers in a farm		No. of total laterals in a farm	
To provide one irrigation how many hours system runs?		To provide one irrigation how many hours system runs?	
No. of irrigation per season?		No. of irrigation per season?	

Part – D : Methods of Land Fertility and Productivity

Name of Compost	**Summer 2009**		**Kharif 2009-10**		**Rabi 2009-10**	
	Total quantity used Kg.	**Note**	**Total quantity used Kg.**	**Note**	**Total quantity used Kg.**	**Note**
Compost / F.Y.M.						
Vermi Compost						
Castor Cake						
Neem Cake						
Other Readymade Compost						
Urea						
D.A.P.						
Single Super Phosphate (S.S.P.)						
Double Super Phosphate (D.S.P.)						
Murate of Potash						
Other Chemical Fertilizers						
Cow Urine						
Liquid Manures						

Detail of Green Manuring taken during last year

Season	**Summer 2009**	**Kharif 2009-10**	**Rabi 2009-10**
Name of Green Manure Crop			

Detail of Crop Residue buried in soil during last year

Season	**Summer 2009**	**Kharif 2009-10**	**Rabi 2009-10**
Crop			

Detail of Crop Residue burnt during last year

Season	**Summer 2009**	**Kharif 2009-10**	**Rabi 2009-10**
Crop			

Detail of Crop Residue Fade to Livestock in field during last year

Season	**Summer 2009**	**Kharif 2009-10**	**Rabi 2009-10**
Crop			

Part – E : Assessment of Energy Consumption and Efficiency of Fuel Used

1. Season : Summer 2009

Type of Usage	Device	Capacity in H.P.	No. of Hours used	Efficiency Ltr./Hr.	No. of K.M. Used	Efficiency K.M./Ltr.
Compost transportation						
Ploughing						
Harrowing						
Hoeing						
Furrow making						
Chemical fertilizer transportation						
Filling compost in furrow						
Sowing						
Making of ridges						
Inter cultivation - 1						
Inter cultivation – 2						
Inter cultivation – 3						
Inter cultivation – 4						
Primary irrigation device						
Secondary irrigation device						
Harvesting						
Transportation of crop from field to threshing yard						
Threshing						
Cleaning						
Transportation to home						
Transportation to market						

2. Season : Kharif 2009-10

Type of Usage	Device	Capacity in H.P.	No. of Hours used	Efficiency Ltr./Hr.	No. of K.M. Used	Efficiency K.M./Ltr.
Compost transportation						
Ploughing						
Harrowing						
Hoeing						
Furrow making						
Chemical fertilizer transportation						
Filling compost in furrow						
Sowing						
Making of ridges						
Inter cultivation - 1						
Inter cultivation – 2						
Inter cultivation – 3						
Inter cultivation – 4						
Primary irrigation device						
Secondary irrigation device						
Harvesting						
Transportation of crop from field to threshing yard						
Threshing						
Cleaning						
Transportation to home						
Transportation to market						

3. Season : Rabi 2009-10

Type of Usage	Device	Capacity in H.P.	No. of Hours used	Efficiency Ltr./Hr.	No. of K.M. Used	Efficiency K.M./Ltr.
Compost transportation						
Ploughing						
Harrowing						
Hoeing						
Furrow making						
Chemical fertilizer transportation						
Filling compost in furrow						
Sowing						
Making of ridges						
Inter cultivation - 1						
Inter cultivation – 2						
Inter cultivation – 3						
Inter cultivation – 4						
Primary irrigation device						
Secondary irrigation device						
Harvesting						
Transportation of crop from field to threshing yard						
Threshing						
Cleaning						
Transportation to home						
Transportation to market						

Name of Surveyor :-____________________