CLIMATE PROOFING
BIO-INTENSIVE RAINFED FARMING SYSTEMS

ACCION FRATERNA ECOLOGY CENTRE
ANANTAPUR, INDIA

Produced by ALTERRA, Accion Fraterna
Commissioned by ICCO

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Summary & Conclusions

Bio-intensive rain-fed farming is a sustainable way of agriculture for small and marginal farmers requiring a minimum of external inputs. It consists of an agro-horticulture cropping integrated with dairy farming making use of available off-season labor. Apart of some regular watering during the establishment of the per-annuals, irrigation is not needed.

The cropping plan indicates field and alley crops which provide various functions to the farm and field like protection against wind, high temperatures and downpours and drought spells protection against insects, diseases and rooming cattle. Shading by multilevel crops, additional water for short and deep rooting crops, manure for chemical and physical improvement of the soil, use of fodder for cattle and as straw for alley crops makes it an integrated and self confined system. It provides food, basic income as well as high market price income with opportunity crops cooping instable market prices.

Climate change effect over the period 2040-2080 may results in higher temperatures: 2-3 degrees under the 'business as usual' scenario and 1-2 degrees under the 'sustainable path' scenario. The shady and transpiring conditions of agro-horticulture will create a moderating microclimate by reducing the depletion of soil moisture and oxidation of mulch and organic matter and increasing crop production by keeping the stomata open for assimilation during the day.

Because climate change the rainfall will be at longer intervals with pour-downs. If build well on the contour with sufficient straw and storm pits where needed, any type of rainfall can be captured. More prolonged precipitation will reach the lower root zone supplying the deep rooting crops.
In between the pour-downs longer periods of no rain have to be expected up to 2 to 3 weeks In order to keep water for the field crops sufficient organic matter need to be added to the field by a mixture of manure and mulch. This is within the capacity of this farming system.

Over the whole year it is expected that the rainy season of SW and NE monsoon will be longer of duration making a second rain-fed crop possible. Making farming for small and marginal farmers an even more attractive alternative.

The bio-intensive rain-fed farming is making use of the natural and human resources as they are available with marginal (< 1ha) and small farmers (<2 ha). Multilevel crops and enriched manure balls (Ghana Jeevamrutham) are the major changes from the traditional groundnut cultivation. Where needed cows can be purchased on micro-credit which proves to be profitable after 6 months already. In general labor is sufficient available and in off-season rural system NREGA a solid source of living avoiding any climate and market uncertainties of mono cropping.

At some point labor, manure or fodder may have to be acquired; this will be possible by additional income from the intensive farming. The approached of bio-intensive farming may only feasible for bigger landowner with more cattle and if a higher degree of mechanization is allowed.

Accion Fraterna Ecological Centre shows flexible in its targets by moving from health and education, towards soil and water conservation in the watershed and after dry periods with regional famine introducing of fruit trees like Tamarind and Mango for income diversification, extended towards the bio-intensive rain-fed farming as promoted to-day.

Integrated agrohorticulture system is a good alternative for small and marginal farmers as it make use of available resources, has low external input and provide a certain variety of products during the year for food and market.

1 Introduction

Objectives of the study

The objectives of this study are to assess the climate robustness of the bio-intensive rain-fed system as propagated by Accion Fraterna Ecological Centre which splits in:

1. the climate change impacts on agro-horticultural system and the effectiveness of already proposed measures (climate proofing);
2. is sustainable agriculture as feasible alternative for the marginal and small farmers as response to climate chance impacts;

Figure 1: Location of Anantapur district in Andhra Pradesh state on the map of India

Accion Fraterna Ecolocial Centre

Accion Fraterna , founded by father Ferrer, operates in the area of about 100 km around Anantapur to improve sustainable rain-fed agriculture. The activities of AF changed over the years. Initially AF focus was on people welfare in the villages through health care and education (1982) . After a prolonged drought more attention was given to the watershed in order to assure sufficient drinking water and water for food production (1986). After successful development this activity was handed over to the government and AF concentrated to the small and marginal groundnut farms towards sustainable agricultural practices (2007).

With population growth and priority to commercial crop farming many traditional (fruit) trees were cut for firewood and extention of agricultural land and groundnut income farmers strongly became dependent on weather extremes like sunshine, wind and rainfall variations. The traditional Mango and Tamarind was (re-)introduced by AF at field boundaries and in a next phase developed towards a more eco-intensive intercrop farming representing an agro-horticulture system with a combination field crops, fruit trees, catch and fodder crop in combination with cattle both for food and cash income. With some initial irrigation the seedlings survive dry periods and after establishment grow and produce with water from the deeper root zone.

The target is a low input and carbon free agriculture with increased labor input outside the peak period. In combination with the governmental rural labor programme NGERA this bio intensive agriculture counteracts to (seasonal) migration. The AF programme subsidized the farmers for weekly irrigation during the dry periods for the first 2 years in addition to selected seeds or planting material and advise.

Accion Fraterna is active in 214 villages in 8 Mandals reaching 46.000 farmers and 146.700 ha in an area of about 100 km radius from Anantapur. The AF direction is supported by a team of participatory monitoring and evaluation (PME), and a small team of subject matter specialists B.Kondaiah and S.A. Rahman on agriculture and B. Lakshmi Kantham on watersheds., and for the field 4 area team leaders (ATL) for two mandals each with administrative and technical support in working areas: Atmakar, Kundurka, Kalyandurg and Dharmavaram, each with about 8 Socio Technical Organisers (STO) as field staff. At community level there are village activists, Grama Sasya Mithra Samakhyas and Sasyamithra groups. At state level AF cooperates and divide tasks with a wider network of rural development organizations.

The area of study

Anantapur, (14.68ºN and 77.6ºE altitude 335m) is the capital of Anantapur district with an area of 100 km x 190km situated in the southern part of Andhra Pradesh. The District of Anantapur has a fairly good elevation which provides the District with tolerable climate throughout the year.

Its northern and central portions are a high plateau, generally undulating, with large granite rocks or low hill ranges rising occasionally above its surface with in the north more black cotton soils and in the middle working area of Accion Fraterna, arid treeless, red soils and in the southern portion of the district the surface is more hilly with average sandy red soils of normal productivity. The soils are little developed of loamy sandy soils and hard to cultivate with exception with some alluvial stretches.

Anantapur has a semi-arid climate, with hot and dry conditions for most of the year. The geographical position of the Peninsula render it, the driest part of the state and hence, agriculture conditions are more often precarious. Monsoons also evades this part due to its unfortunate location. Being far from the East coast, it does not enjoy the full benefits of North

East monsoons and being cut off by the high western Ghats, the South West monsoon are also prevented from penetrating. The normal rainfall of the district is 553 mm. The normal rainfall for the SW monsoon is 380 mm. The failure of the rains in this SW monsoon period of June to September will lead the District to drought and failure of crops. The rainfall for NE monsoon is 180 m only from October to December. Total annual rainfall is about 560 mm with local differences from 250 to 700 mm. Over the years 80% of the annual precipitation is between 300 and 800mm.

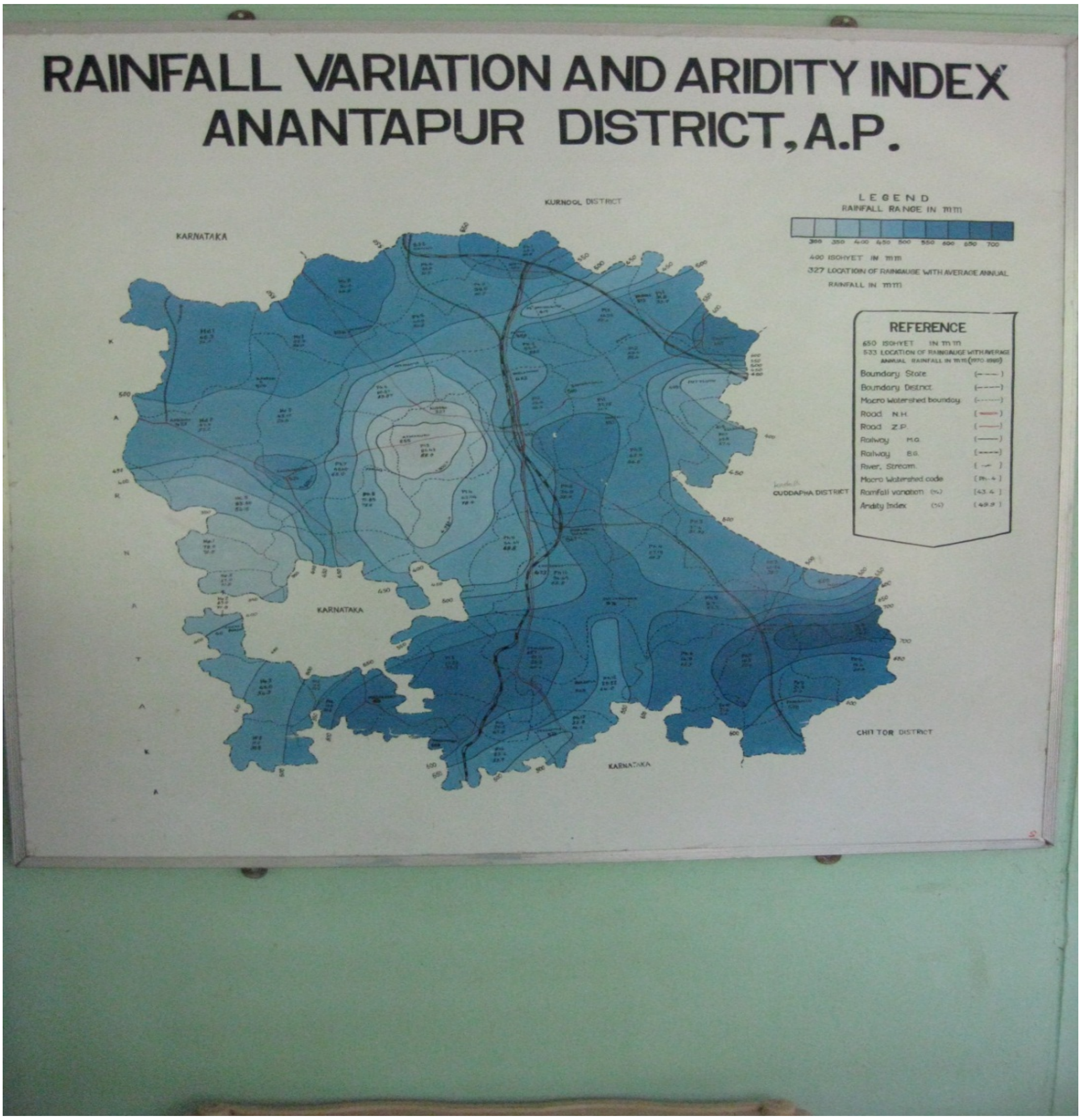


Figure: rainfall distribution over the Anantapur district (source: map AF office)

The other months are almost dry March, April and May are warm months when the normal daily maximum temperature ranges between 29.1 C to 40.3 C. November, December and January are cooler months when the temperature falls about 15.7 C.

Chitravathi River

A significant river in the district is the "CHITRAVATHI" and crosses the AF working area. Its origin is in the west in the state of Karnataka. This river enters the District near Kodikonda village of Chilamathur Mandal and flows North over Rocky and Hilly uplands of Gorantla, Puttaparthi, Bukkapatnam, Kothacheruvu, C.K.Palli, Dharmavaram, Bathalapalli, Tadimarri and Yellanur mandals and falls into Pennar River at Gandikota in Cuddapah district in the east.

The total geographical area of the district is 19.100 km2. of which 48.25% of the total area is sown. Of the cropped area 90% is cultivated in Kharif and 20% in Rabi Season during the year 2006-2007. Anantapur district occupies the lowest area of irrigation facilities with only 14% of the gross cropped area.
Groundnut (Arachis Hypogaea) is with about 485.000 ha the main field crop in Anantapur with modest water requirement and relative high cash return. Most groundnut (80%) is cultivated with contingency intercrop like pigeon pea or Redgran (Cayanus Cayan), cow pea (Vigna Unguiculata) , and Castor (Ricinus Communis) . They are interplanted in single rows at 4-6 m apart being the advice of the Agriculture department. In general groundnut receive some very low doses of NPK fertilizer; 20% of the farmers however tend to give too much.

Accion Fraterna’s bio-intensive farming pilots reaches about 3.400 farmers or about 7 % of the 46.000 marginal and small farmers in AF guided villages and it covers 2.310 ha or 1,6 % of the area.

No	CATEGORY OF FARMERS	AVREAGE LAND HOLDING IN Ha.	FARMERS		AREA	
			No	%	Ha.	%
1	Marginal Farmers	< 1.00	167.972	34,62	92.691	10,01
2	Small Farmers	1.00 - 2.00	153.675	31,67	222.908	24,07
3	Semi-Medium Farmers	2.01 - 4.00	118.847	24,49	299.868	32,38
4	Medium Farmers	4.01 - 10.00	38.995	8,04	224.182	24,21
5	Large Farmers	> 10.00	5.763	1,19	86.351	9,33
TOTAL FARMERS & AREA OF GROUNDNUT			485.251	100	926.000	100

table: Type, number of farmers & extent of groundnut cultivation in Anantapur district

Cropped area may change over the years. For soybean cropped areas have been observed

2 Bio-intensive rain-fed farming system

The farming system propagated by AF offers poor and marginal groundnut farmers operating in a risky monoculture environment the opportunity to build a more varied low input farming system making use of the resources available at and produced by the farm.

This bio-intensive intercrop farming is an agro- horticulture system with field crops, fruit trees, catch and fodder crops integrated with animal husbandry based on an interchange of fodder and manure. For these farmers two milk cows is sufficient and can be acquired through micro-credit. The whole farming secures both food and cash income.

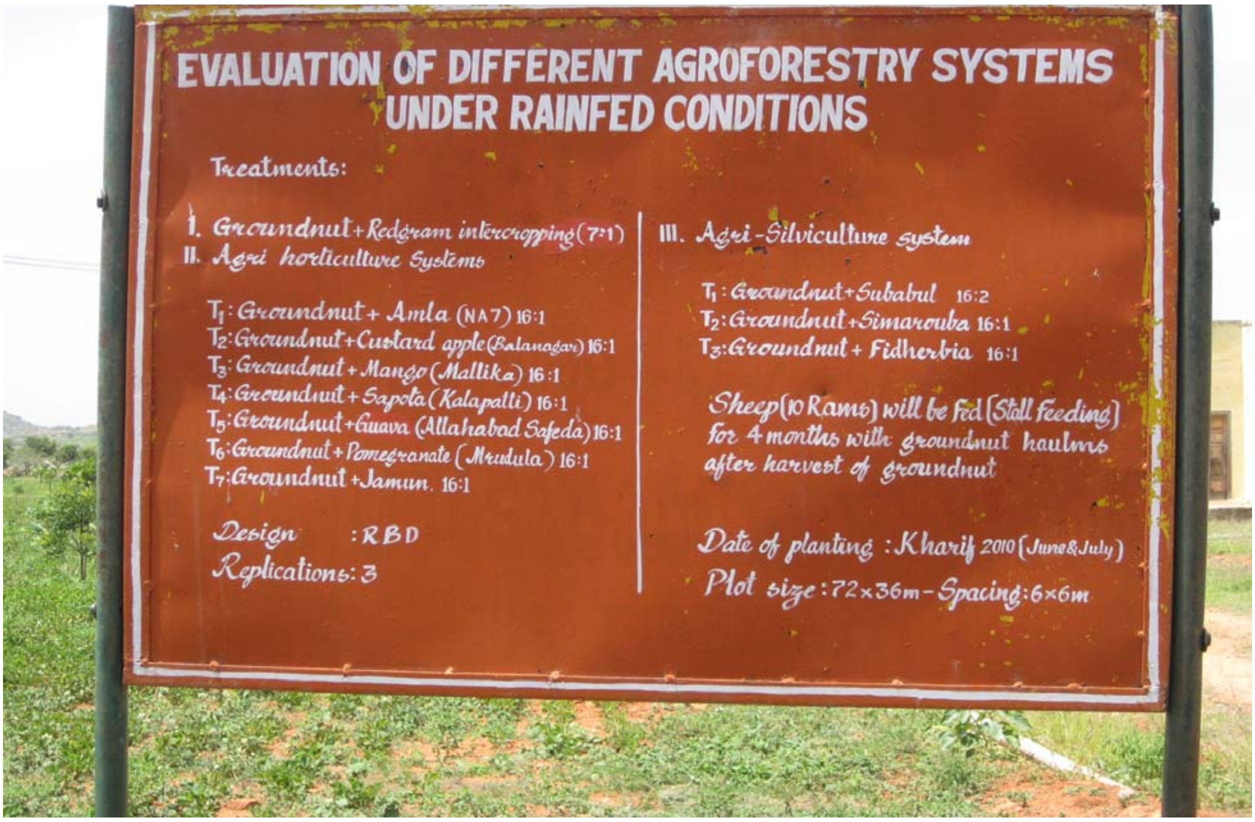


Figure: intercropping plan for intensive bio-intensive rainfed farming Kalyandurg

In the field plan three types of crops can be distinguished: field crops, intercrops and border crops with complementary functions like fruits, fodder, pulsed, grains, wind brakes, shade, trapping insects, fungi and diseases. The above figure shows an overview of the whole system and annex 3 gives a more precise cropping plan. During this visit no full grown fields has been visited; the oldest was 2 years.

The crops occupy different space, reach till various heights and take their water from different soil layers. This sustainable agriculture maintains a stable fertility and good hydrological conditions in the root zone and a moderate micro climate even under extreme climate conditions. The farming practices are: permanent soil cover, low tillage, multiple level and intercrop planting based on a rich organic soil.

Sustainable agriculture is mainly based on two strategies

1. Low carbon agriculture by avoiding mineral fertilizer for reduced GHG
2. Sustainable use of natural resources and low input agriculture.

Low carbon agriculture by avoiding mineral fertilizer for reduced GHG like CO_2, NH_3, N_2O is a CC mitigation measure. The main activity is the use of (enriched) organic matter by planting and regular periodic gifts. The material comes in principle from the farm itself. One cow can provide manure for 30 acres and often two head are kept by a family of 2 to 5 acres. The manure will be enriched and formed to 15 cm balls which can be stored for more than a year –Ghana Jeevamrutham . In addition the field provides fodder crop leaves and other green manure to be used to main the fertility of the soil again. The manure will increase the biological activity in the soil which also reduces the chance for pests and disease and makes P and K fixed into the soil complex available to the plant. The objective is not to use any chemicals for fertilizer, pests and diseases. Organic matter improves the soil structure by creating macro pores of the soil and increasing its water holding capacity. Most of the Ghana Jeevamrutham is placed in the rows of fruit trees and fodder. Mulching is practicing now here and there in basins for fruit plants. No mulching was taken up for annual crops due to scarcity of biomass. The organic matter content in Anantapur soils is very low (below 1%).

Figure: difference of soil color and structure between open field and alley rootzone

Sustainable use of natural resources makes it possible that very little inputs form outside the farm are needed; no NPK is needed. These strategies are also applicable in rice fields. The irrigation application is reduced and in an extended rotation. As rice production is only marginal reduced the crop per drop increases considerable. In addition enriched fluid organic matter Jeevanrutham (Life Food) is applied to the field injected with Azola releasing N from the atmosphere. Single seedling planting is applied on experimental basis (System Rice Intensification SRI).

Sustainable agriculture seems a solid and self-containing system. For the CC assessment of the system it is required to describe the actual climate change and impacts. It is good to realize that other global developments may have bigger influence on the rural livelihood as a whole and their farming specifically than Climate Change ever will have.

3 Climate trends and climate projections

This chapter indicates the projected climate impacts and how the climate projections has been established. Annex 2 shows this more in detail with considerations for future use.
During the preparation the field visit finally use has been made of regional climate modelling (RCM). The coarse resolution of GCMs makes it difficult, though not impossible, to assess future climate change in Anatapur from the models. IPCC AR4 provided therefore only projections of climate change for a larger region in South Asia (SAS).

Within this project, scenarios will be used that capture the possible climate changes that can be expected for a large part of the Anantapur district in India. Most climate change projections are made for the 21st century, but in this project we will limit ourselves to climate change projections which are representative for 2050 and 2070.

The simulations for the 21st century are simulated using the various emission scenarios (IPCC SRES scenarios, SRES: IPCC Special Report on Emission Scenarios) and are projections of future climate change. Figure 1 shows a scheme in which the various emission scenarios are described in more detail. The SRES storylines were constructed on two axes from the drivers below, i.e. the degree of globalization versus regionalization, and the degree of orientation on material versus social and ecological values (see Figure 1). The storylines describe developments in many different social, economic, technological, environmental and policy dimensions. The storylines relevant for this project are the A2 (regional economic development) and the B1 (global sustainable development) which is considered as the most preferred to slow down climate change development.

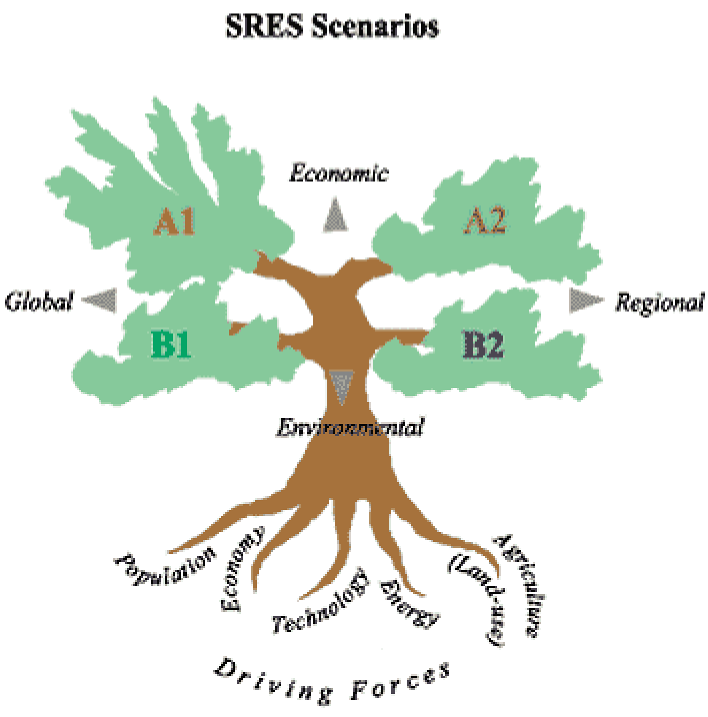


Figure 3 Schematic illustration of SRES scenarios. The four scenario "families" are shown, very simplistically, as branches of a two-dimensional tree. (IPCC, 2000)

The new regional projection method was developed by EU Watch project producing multi-model based projections for the terrestrial components of the global water cycle for the 21st century. The advantage of this projection compared with the IPCC scenarios is that the resolution is finer (0.5 x 0.5 °) and that the different projections are bias corrected. The bias correction means in this case the correction with the models EC/ECHAM, IPSL and CNRM and the linkage with available meteorological and environmental data. The finer scenarios are based on two SRES-scenarios: A2 (“business as usual”) and B1 scenario (“sustainable path”).

3.1 Current situation

From the Agricultural Research Station at Anantapur (ARS Anantapur) a large dataset was collected with all kinds of various meteorological parameters. This dataset range from 1985-2010 and the precipitation dataset even ranges from 1969-2010. From this datasets it was decided to look at both temperature and precipitation as these variables are most important to assess climate change scenarios. Figure 3 shows the temperature observations and Figure 4 shows the precipitation amounts both recorded at ARS Anantapur. From the temperature figure we can observe a fairly constant average temperature over the last 25 years. The precipitation shows more variability with higher yearly sums occurring more frequently in the last period of the observational dataset.

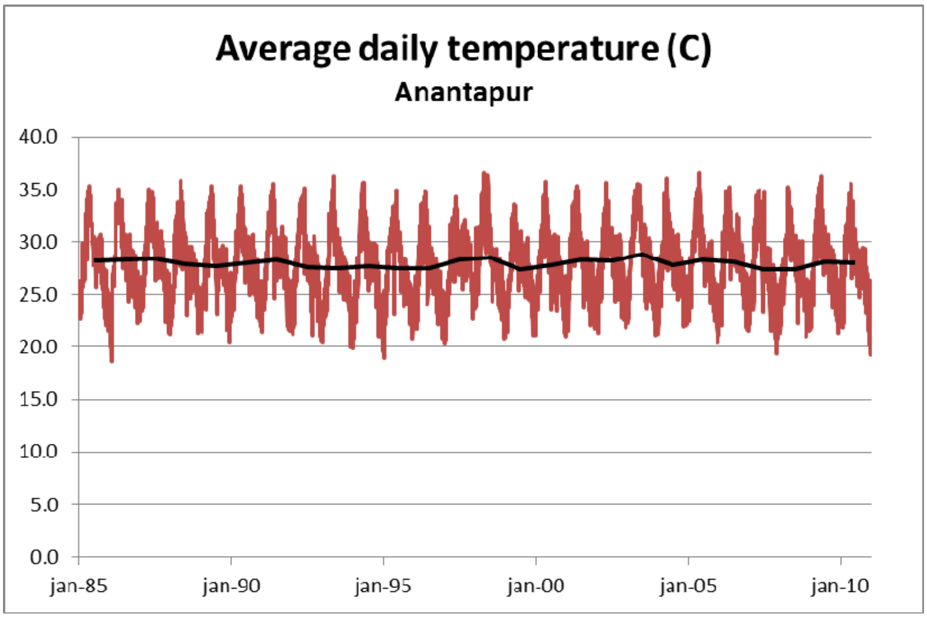


Figure 3: Average daily temperature (°C) (red) at Anantapur and the average yearly temperature (°C, black)

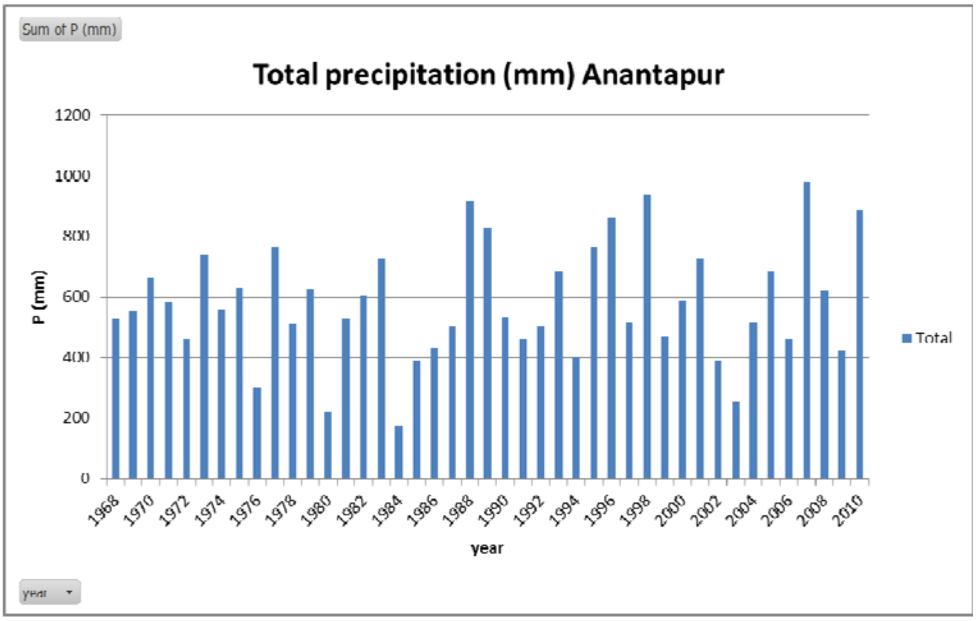


Figure 4: Annual precipitation sums (mm) at ARS Anantapur

3.2 Climate projections

The results shown in this paragraph focus on Anantapur. Figure 4 shows the projections of temperature for the three models and for an ensemble of the models. This will be done for both emission scenarios A2 and B1. The ensemble is simply the arithmetically average of the three models per scenario.

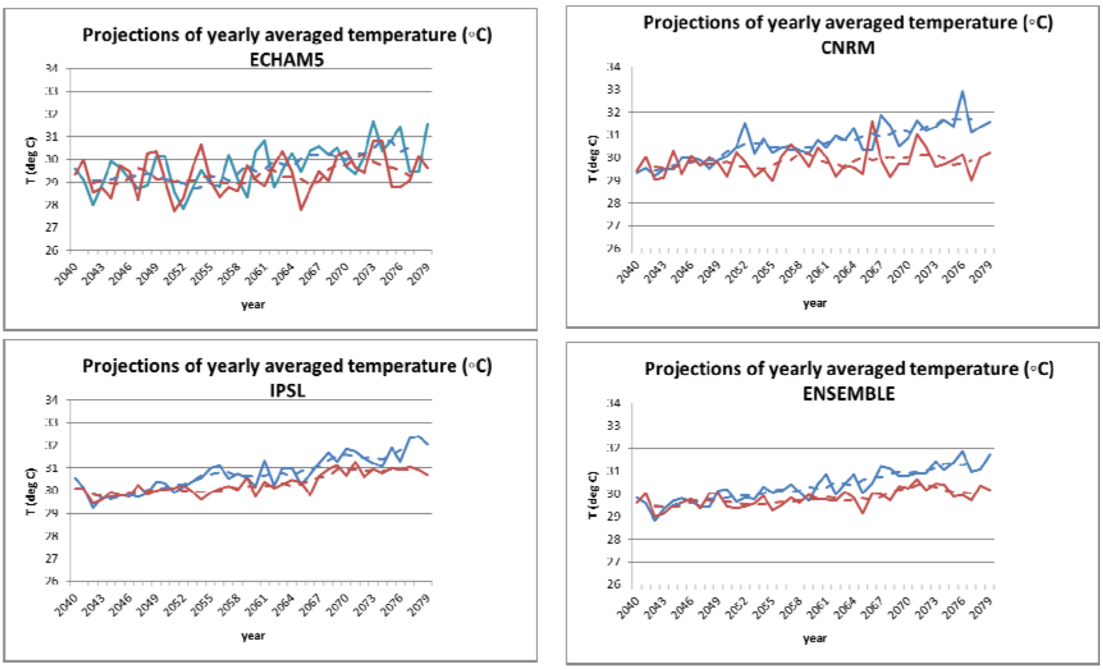


Figure 4: Projections of temperature at Udaipur for ECHAM (upper left), IPSL (upper right), CNRM (lower left), ensemble of models (lower right). Blue: A2 scenario (dashed: moving average of 5 years), light green: B1 scenario (dashed: moving average of 5 years)

While looking at the results for the downscaling experiment performed for Anantapur we can certainly see a trend in all models that the average yearly temperature is about to rise in the A2 scenario. In the (moderate) B1 scenario this rise is not so clearly seen and the model don't agree. The IPSL model shows a rising trend in temperature of about two degrees in the A2 scenario between 2080 and 2040 and one degree in the B1 scenario. This model also shows the highest temperature for the area of interest. The ECHAM model shows a lot more variability between years and shows even a cooling trend in the decade 2070-2080 for both scenarios. The B1 scenario of the CNRM model shows a marginal increase in temperature. If we compare the projections with the observed temperature we can clearly see that the average temperature is clearly higher in the projections, regardless of the scenario or model used, than in the observations over the last decennia.

Table 3 shows a table with the maximum and minimum daily averaged temperature per 5 year period and for the growing seasons in these 5 year period. The growing season is defined from month 6 to month 12. This analysis is only executed on the ensemble of the models for both A2 and B1 scenario. The extremes seem to increase stronger in the A2 scenario than in the B1 scenario. The maximum temperatures tend to cross 35 degrees at the end of the selected period for the growing season in the A2 scenario. This temperature is crossed already more frequent outside the growing season. This holds also true for the B1 scenario.

GROWING SEASON		ENS A2		ENS B1	
5 year period		MAX	MIN	MAX	MIN
2040	2044	33.91	23.03	33.43	22.81
2045	2049	34.55	22.78	34.14	23.30
2050	2054	34.28	23.23	35.27	22.66
2055	2059	34.28	23.48	34.28	22.66
2060	2064	34.99	24.41	34.31	23.26
2065	2069	35.07	24.29	34.77	23.68
2070	2074	35.65	25.20	34.49	24.52
2075	2079	36.63	25.44	34.92	23.77

WHOLE YEAR		ENS A2		ENS B1	
5 year period		MAX	MIN	MAX	MIN
2040	2044	36.44	22.82	36.57	22.81
2045	2049	36.21	22.78	36.75	22.75
2050	2054	36.96	23.23	36.50	22.66
2055	2059	37.95	23.48	37.57	22.66
2060	2064	37.64	24.41	37.41	23.26
2065	2069	37.49	24.29	36.89	23.68
2070	2074	38.18	25.18	37.77	24.52
2075	2079	38.88	25.32	37.30	23.77

Table 3: Maximum and minimum daily averaged temperature per 5 year period for both growing season (upper part) and the complete dataset (lower part)

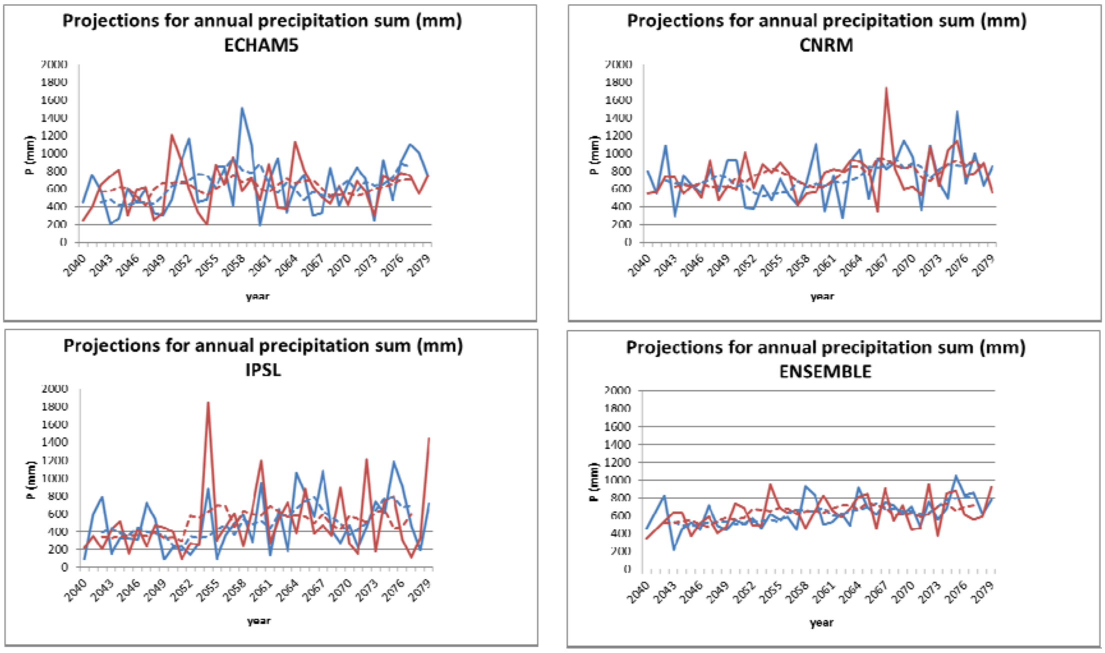


Figure 5: Projections of precipitation at ARS Anantapur for ECHAM (upper left), IPSL (upper right), CNRM (lower left), ensemble of models (lower right). Blue: A2 scenario (dashed: moving average of 5 years), light green: B1 scenario (dashed: moving average of 5 years)

Figure 5 shows the climate projections for annual precipitation at Anantapur. All models show an increase in precipitation between 2040 and 2080. The variability is high in all models and scenarios. If we take a look at the precipitation in the 'ensemble', it doesn't matter which scenario is used as both scenarios show the same kind of trend in the annual precipitation. The extreme events are not really visible in these graphs and therefore Table 3 is designed.

COUNT(2040-2060)	EC_A2	CNRM_A2	IPSL_A2	EC_B1	CNRM_B1	IPSL_B1
p>50 mm	31	36	12	26	36	20
p > 100 mm	2	3	0	3	4	5
p > 150 mm	0	1	0	0	1	2
COUNT(2060-2080)	EC_A2	CNRM_A2	IPSL_A2	EC_ B1	CNRM_B1	IPSL_B1
p>50 mm	33	51	26	31	46	22
p > 100 mm	0	10	11	1	8	9
p > 150 mm	0	1	5	0	0	2

Table 3: Projections of count of certain precipitation events at Anantapur for all three climate models and two emission scenarios.

This table shows the occurrence of a certain event per day in the climate projections. We have defined a daily rainfall sums of at least 50 mm as an extreme event. The period of 2040-2080 is split in two parts to show if a change is observed in the extreme events. We can conclude from this table that CNRM_A2 and IPSL_A2 show an increase in extreme events. The other B1 scenario shows a delayed change in extreme events.

Another important variable is the amount of rainy days in a year. This may say something about the duration of the monsoon season. Figure 6 shows the total number of rainy days per year. Per 5 year block an average is taken. We conclude that for all scenarios and model the number of rainy days per year will rise. The CNRM model tends to be wetter than the other two models. The conclusion of this analysis is that the monsoon period is more likely to increase with more rainy days and the days with heavy rainfall increasing slightly. However, more research is needed to analyse if the onset of the monsoon is earlier or that the monsoon is likely to last longer.

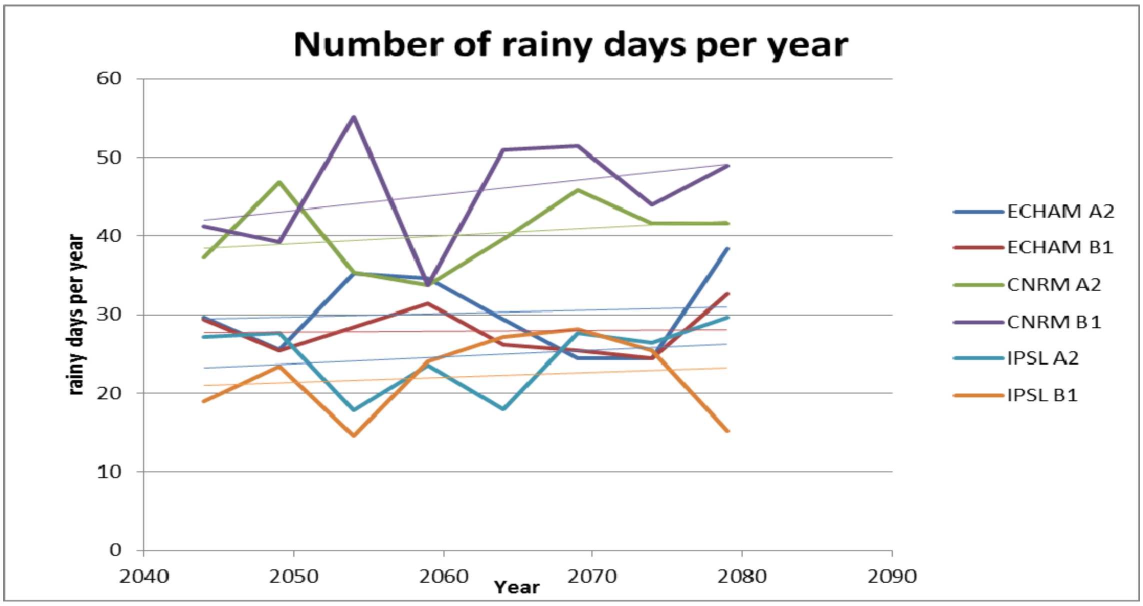


Figure 6: Projections of the number of rainy days per year (averaged per 5 year) for the various models and scenarios. The fine line is a linear regression per model and scenario.

Concluding remarks

The temperature show for all models a rising trend for both emission scenarios although the increase in the B1 scenario is only marginally. Based on the data available at this moment we can conclude that it is likely that the temperature will rise, but that the magnitude of this increase is dependent on the emission scenario. The precipitation projections shows an increase in annual precipitation with more rainy days per year and a slight increase of extreme events. Based on these findings we conclude that rainfall will fall over a longer period leading to a longer monsoon period. Some climate projections confirmed this hypothesis, but more analyses are actually needed to confirm this.

4 Multilevel cropping and microclimate

Crop production may be at risk in the future due to increasing competition for water and increasing variability in temperature extremes (Rosenzweig et al., 2004). This may represent a vulnerability for many rural households that depend on rain-fed agriculture for their livelihoods. According to Lin (2007), shade trees used in agroforestry systems offers an effective coping mechanism to implement in agricultural areas that suffer from climate extremes. This researcher mentions that temperature, humidity, and solar radiation fluctuations increase significantly as shade cover decreases; soil data showed larger fluctuations in soil moisture if little shade is available.
Overall, the amount of shade cover can be related to a more stable microclimate and soil moisture for the crop of interest. The use of agroforestry systems is an economically feasible way to protect crop plants from extremes in microclimate and soil moisture and should be considered a potential adaptive strategy for farmers in areas that will suffer from extremes in climate.

Anantapur situation
The introduction of agro-forestry or agro-horticulture as it is applied in the Anantapur region is a good adaptation measure against the increasing climate variability and higher temperatures. In literature not much is found about the optimal planting density of used trees, tree species and the type of crops that can be planted underneath the trees. Note that tree roots extract water also from deeper soil layers and the competition between trees and crops planted underneath is limited. Generally, the advantages are larger than the negative effects of water competition. To quantify to what extend the air humidity increases and the water requirement decreases as a result agro forestry/agro horticulture, more research is needed.

Climate change effects
The AnantapurA2 and AnantapurB1 spreadsheet can be used to estimate the effects of the increasing relative humidity on the potential evapotranspiration and the amount of water needed to obtain a maximum yield. The formulae underlying these spread sheets are derived from the FAO website (http://www.fao.org/docrep/X0490E/X0490E00.htm). Note that A2 and B1 stand respectively for the A2 (regional-economy) scenario and the B1 (global sustainable) scenario. In the A2 scenario the temperature increases stronger than in B1 scenario and consequently the potential evapotranspiration is higher.
By changing the section Temperature Increase and the section RH2 the effects of temperature increase and increasing relative humidity can be estimated. For example: Suppose that in the A2 scenario due to planted trees the field temperature increases 0.5 degree less, the relative humidity increases with 20%. Will so reduce the potential evapotranspiration about 6% in winter and 13% during the SW monsoon. Under agro-horticulture conditions the wind speed will reduce and consequently the evapotranspiration will reduce even more.

Farmers confirm that shade of trees and alley plants has a moderating effect on the temperatures for the alley and the field crops. This can be related to the shade side of the trees as well as their transpiration. Trees also break the wind and might create higher humidity which lowers the evapotranspiration but may increase the chance on diseases.
Farmers are also aware on the effect of NPK on the drought resistance of field crops. If water is short for one week, field with NPK treatment will suffer after 5 days already, while manure application can stand up to 10 days. Manure is applied together with straw in a concentrated way in the tree basins and Alleys. Improvement on manures enrichment an straw for the field crops could increase infiltration and water holding capacity of the soil.

5 Eco-intensive farming an appropriate adaptive measure

In this chapter conclusions of the effects of climate change projections for the 1040-1070 period and farmers experiences will be connected with the eco-intensive which integrates an agro-horticulture system with cattle husbandry. Also attention is paid to rural developments which may be expected in the coming years.

5.1 Climate effects

Temperature rise

Farmers do note temperature rise but mainly as drought. They note heat in vegetables and start irrigation for 'cooling' of the crops.
Temperature is expecting to rise towards the year 2070 notably under the business as usual scenario (2ºC) and moderate under the sustainable path scenario (0,5ºC). This may lead to higher production if water is sufficiently available. Crop water use may increase and drought levels reached earlier, which may result in production loss.
More serious are the temperature extremes at day time which may cause closing of the stomata and equally loss of production. During cropping period temperatures may rise with 1.5 - to 2.5ºC. The temperature rise outside the cropping season will affect the health of the perennial crops and trees as well as increase the oxidation of the organic matter in the soil.

The crops and trees selected in the farming system can stand the heat stress. The temperature rise in the ground and at the crop will be moderated by the cooler microclimate by the shade created by the multi-layer alley plants. This will reduce oxidation of organic matter and to high levels of transpiration maintaining even reasonable levels of humidity in drier periods. The negative effects of shade can be reduced by trimming of the crops. Eventual diseases and plagues are avoided by the close border crops included catch crops. Also the spacing between the alleys can be subject of further research.

Dealing with heavy rainfall

The farmers experience high intensive and erratic distributed rainfall. This can be explained by the extra time needed to fill the warmer air till saturation. Consequently more water will be poured down during the shower events and becomes the rainfall more intensive. Consequently more runoff will occur with consequent erosion, flooding and sediments in the rivers. Most problematic is the loss of water for the field. Important in this respect is a high absorption and storage capacity of the soil water. By the design of the eco-intensive agro-horticulture plots, this runoff is avoided and water will remain available for the crop. Improvement still can be made by planting alley on the contour with storm pits at strategic locations. Mulching by straw and fodder will increase infiltration as well as some degree of tillage. The moderating effect of the multilevel cropping will decrease temperatures and reduce oxidation of mulch and organic matter.

Drought resilience

Farmers are very aware of droughts. The farmers note a higher frequency of dry years; before one dry year in 4 years, now 3 dry years. In the last period indeed dry years were more frequent than in the period from 1988 to 2000 (see figure 4). In the projections however the rainfall rather tend to increase and even the duration of the monsoon is likely to extend. This

will however not increase the precipitation per months but rather the wet period. With consequent growing into the Rabi season. Still intervals of wet and dry years will remain and a mixed cropping with more drought resistant plants seems secured by the eco-intensive farming.
The farmers also note that the dry periods between the rains tend to become longer. This phenomena will continue over time as temperature increase and crops, their roots and the root zone will be subject for adaptation: more drought tolerant crops, better rooting conditions by deeper tillage and increased water holding capacity in the soil. In this way optimum use is made of the water conservation measures mentioned above, contour alleys and storm pits to collect rain water mainly in favor of the alley crops and deep rooted trees. Extra infiltration water in the field can be stored for the field crops by increased water holding capacity by use of manure which now mainly seems applied for vegetables and alley crops.
Because of the multilevel build-up of the alleys, a micro-climate of relative higher humidity will be created, reducing the transpiration of the crops and the oxidation of organic matter, in the day temperature sensitive higher 5-10 cm of the soil.

Mitigation

In relation to climate change mitigation the eco-intensive agriculture please a very positive role as it avoid the production of external greenhouse- gas related products (fertilizer) and avoid, makes intensive use of otherwise wasted products (like manure). Maybe more an adaptation rather than a mitigation measure, is the creation of a microclimate with a cooling effect on its environment. Earlier initiatives of extensive forestation to force climate change towards more rainy conditions.

5.2 Farmers' alternative

Focusing on the small and marginal farmers in the Accion Fraterna working area, we may suppose that the size of their farm and investment capacity is small. Suppose because they may join ownership of land within their family and may have substantial income from outside. In all cases food subsistence is a major criteria and additional cash income from sold products like milk and fruits is most important.
A monoculture of groundnut eventually with contingency crop still will make the farmers dependent on the market and possibly on rainy and drier years. The multi cropping and cattle of the eco-intensive farming already spread the risk by the created moderating microclimate and the special role of organic matter from enriched manure and additional fodder crops. The introduction of fruit trees will also outside the harvest season of groundnut provide food and income over the years.

The increased variability of the precipitation during the growing season will face groundnut farmers for risk of depreciation of crop production. This will be less a problem for eco-intensive farmers as the organic approach will store extreme rainfall in the root zone for the dryer periods and so keep productions levels high where market prices are high as other farmers' crop fails.

The statistics learn that the number of cattle tends to decreases resulting in the price for manure. The need of cattle to complete the eco-intensive farming for small farmers is only two head. This is good to obtain by micro-credit as within half a year the sum can be repaid easily by the sale of the milk. The price of milk only will increase with reduced number of cattle. Still it is not known if the alleys provide sufficient fodder for the cattle. For bigger farmers indeed obtaining sufficient manure may become a burden.

The labor availability is a crucial issue for eco-intensive agriculture as it tends to fully use the available rural labor in small and marginal farms and partly outside the labor peak. This intensive farming in combination of micro-credit and NEGRA will provide additional rural income. In cases where local project are developed with the NEGRA programme which provide families with 100 rupees for 100 working days, living condition can be improved and migration decreased.

Given the growth of the rural population one can imagine that also the group of small and marginal farmers remains growing. The reduced space for agriculture, the desire for consumption goods and the subsequent increasing need for cash makes migration likely which most likely will result in a situation that a group of adult males will leave on temporary basis their village leaving behind their parents, wives and children.

Another external development is the agriculture policies of the government including price policies, the impacts of political promises and the regular subsidies which however focused on the group of rural poor can also deviate to misused and ecologic disasters. An example may be the recent development in drip irrigation systems which increases the crop production in (semi-) dry areas while reducing the overall water use. For small farmers (less than 5 acres) a subsidy is available of 70% from the horticultural department and 90 % of the government on the essential installation of a deep-well. Unfortunately the regulation in the P.A. Water, Land Tree Act does not control the actual over use of the water source as the permit requires that only a minimal distance of 200 m between pump and nothing about discharge and duration of pumping which may easily lead to a drawn-back of the water level and productivity of the source. Good groundwater management in the contrary could be the basis for a sustainable management of all water resources in the watershed as well as in the delta.

For government is the consideration which of the rural investments are most effective for agricultural production and rural development. It is possible that investing in rainfed agriculture and small farmers is more effective than investments in the irrigation especially if this effectively is used for the wasting surface irrigation of rice rather than the proposed drip irrigation of precious vegetables and fruits (own field observations).

6 References

Basha, S.M. *Fruits of Participatory watershed development*, Accion Fraterna Ecological Centre

Biemans, H., Hutjes, R. W. A., Kabat, P., Strengers, B. J., Gerten, D., and Rost, S.: *Effects of Precipitation Uncertainty on Discharge Calculations for Main River Basins, Journal of Hydrometeorology*, 10, 1011-1025, 10.1175/2008jhm1067.1, 2009.

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

Christensen, J. H., Boberg, F., Christensen, O. B., and Lucas-Picher, P.: *On the need for bias correction of regional climate change projections of temperature and precipitation*, Geophysical Research Letters, 35, 6, L20709
10.1029/2008gl035694, 2008.

IPCC: Climate Change 2007: *The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt,M. Tignor and H.L. Miller (eds.), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp., 2007.

Leander, R., and Buishand, T. A.: *Resampling of regional climate model output for the simulation of extreme river flows*, Journal of Hydrology, 332, 487-496, 10.1016/j.jhydrol.2006.08.006, 2007.

Lin, Brenda B, *Agroforestry management as an adaptive strategy against potential microclimate extremes in coffee agriculture*, Elsevier, ScienceDirect, Agriculture and Forest Meteorology 114 (2007) 85-94 (www.sciencedirect.com)

Mitchell, T. D., and Jones, P. D.: *An improved method of constructing a database of monthly climate observations and associated high-resolution grid*s, International Journal of Climatology, 25, 693-712, 2005.

Piani, C., Haerter, J., and Coppola, E.: *Statistical bias correction for daily precipitation in regional climate models over Europe*, Theoretical and Applied Climatology, 99, 187-192, 2010.

Rosenzweig, C., Strzepek, K.M., Major, D.C., Iglesias, A., Yates, D.N., McCluskey, A., Hillel, D., *Water resources for agriculture in a changing climate: international case studies*. Global Environ. Change 2004.14**:**345–360

Reij, C.P., Smaling, E.M.A., *Analysing success in agriculture and land management in Sub-Saharan Africa: Is macro-level gloom obscuring positive micro-level change?* Elsevier, ScienceDirect, Landuse policy 25 (2008) 410-420

Sanches, Pedro, Soil fertility and hunger in Africa, Science Compass, Policy Forum (2011) (www.sciencemanag,org)

Shambu Prasad C, System Rice Intensification - Innovation history and institutional challenges (2006), WWF International - ICRISAT Dialogue

Trenberth, K. E., Dai, A., Rasmussen, R. M., and Parsons, D. B.: *The changing character of precipitation*, Bulletin of the American Meteorological Society, 84, 1205-+, 10.1175/bams-84-9-1205, 2003.

V&A Programme. *Vulnerability and Adaptation experiences from Rajasthan and Andhra Pradesh* (2009) Swiss Agency for Development Cooperation

Annex 1: Itinerary

Travel days 19-20 and 28-29 September

Tuesday 20/9
meeting Mala Reddy director, Kondaiah & Rahman Agriculture section.

Wednesday 21/9
Kuderu (Mandal) (30km NW of Anantapur) 1
Jayapuram (village +40km): Manure balls (Ghana) and fluid Jeevamruth, and discussion
2 Karutlapalli: Field with plan for intercropping, with mix tree, and red gram as intercrop in groundnut; new irrigation system on slope.
3 Application for subsidy tree inter cropping along flood plain

Thursday 22/9
Dharmavaram (Mandal) silk city, 2nd mandal Rapthadu
4 In 2 years old tree crops, intercrop of groundnut. One tamarind tree. For 3 brothers deep well
5 Newly reclaimed land after land levelling of complete flood plain over gully bed.
6 Palabavi (active women group)

Friday 23/9
Anantapur close to Devara konda (God's hill), Acharya NG Ranga Agricultural University, Hyderabad.
7 Agricultural Research centre Rekulakunta (NE 12 km from Anantapur, near Devara Konda: God's hill)
8 Agriculture Demonstration Farm, Krishi Vignan Kendra, Reddipalli farm (15 km NE of Anantapur)

Saturday 24/9
Kalyandurg (taluk) Bio intensive farming system in rain fed areas Demonstration plot In Kalyandurg working in 4 mandals
9 Farm with 2 acre field 4-type intercrop with reference field
10 Horse gram as alternative crop
11 Village meeting at Kundurpi (20-40 farmers)
12 Yerragunta village with full organic multilevel tropical fruit garden

Monday 26/9
13 Watershed section Accion Fraterna Ecology centre
14 Raminepalli, L.C.F. Paddy experiment plot (15km S)

Tuesday 27/9
15 Horticulture department Anantapur district

Wednesday 28/9
Anatapur
Reporting, presentation travel to Bangalore

Thursday 29/9
Travel and missed meeting with Dr Rupela from ICRISEAT
International Crop Research Institute for Semi-arid and Arid Tropics

Annex 2: Climate Scenario development Anantapur

(Herbert ter Maat, Alterra)

The climate change impacts will be addressed using climate change scenarios which are developed recently. Various scenarios, ranging from coarse to finer resolution, will be described in this chapter. The first paragraph deals with an introduction of climate change scenarios combined with a historical review of the development of climate change scenario. The current state of Global Climate Change scenarios are discussed first. The following section will deal with biases in Climate Change Scenarios and how to correct for them. We conclude with an analysis of the developed scenarios and discuss the successes and shortcomings of the development of Climate Change scenarios for the province of Rajasthan in India.

Introducing Climate Change Scenarios

Within this project scenarios will be used that capture the possible climate changes that can be expected for a large part of Anantapur and surroundings in India. Most climate change projections are made for the 21st century, but in this project we will limit ourselves to climate change projections which are representative for 2050 and 2070.
Climate Change projections are performed on a global scale by various institutes in the world. This leads to an ensemble of models which have their own characteristics. Table 1 shows a selection of the Global Climate Models (GCMs) which are reported in the latest IPCC reports as well. The contribution of Working Group I to the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) was released in 2007. IPCC (2007) assessed amongst other “the capacity of global climate models (…) for projecting future climate

Table 1 Selection of GCMs which are used in IPCC 4AR

Model acronym	Full name of model and institute of origin
CNRM-CM3	**CNRM** Météo-France/Centre National de Recherches Météorologiques, France
GIER	GISS-ER, NASA Goddard Institute for Space Shuttles, USA
GFCM21	GFDL-CM2.1 US Dept. of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory, USA
INCM3	INM-CM3.0 Institute for Numerical Mathematics, Russia
IPCM4	**IPSL-CM4** Institut Pierre Simon Laplace, France
MIMR	MIROC3.2(medres) Center for Climate System Research (The University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC), Japan
MRCGCM	MRI-CGCM2.3.2 Meteorological Research Institute, Japan
MPEH5	**ECHAM5/MPI-OM** Max Planck Institute for Meteorology, Germany
HadGEM	UKMO-HadGEM1 Hadley Centre for Climate Prediction and Research / Met Office, UK
HadCM3	UKMO-HadCM3 Hadley Centre for Climate Prediction and Research / Met Office, UK

change. Climate model ensemble simulations were performed for the 20th and for the 21st century. The simulations for the past 20th century are used to validate the models. The simulations for the 21st century are simulated using the various emission scenarios (IPCC SRES scenarios, SRES: IPCC Special Report on Emission Scenarios) and are projections of future climate change. Figure 1 shows a scheme in which the various emission scenarios are described in more detail. The SRES storylines were constructed on two axes, i.e. the degree of globalization versus regionalization, and the degree of orientation on material versus social and ecological values. The four clusters were given simple names (see Figure 1). The storylines describe developments in many different social, economic, technological, environmental and policy dimensions. The storylines do not have a particular order, but they are listed alphabetically and numerically.

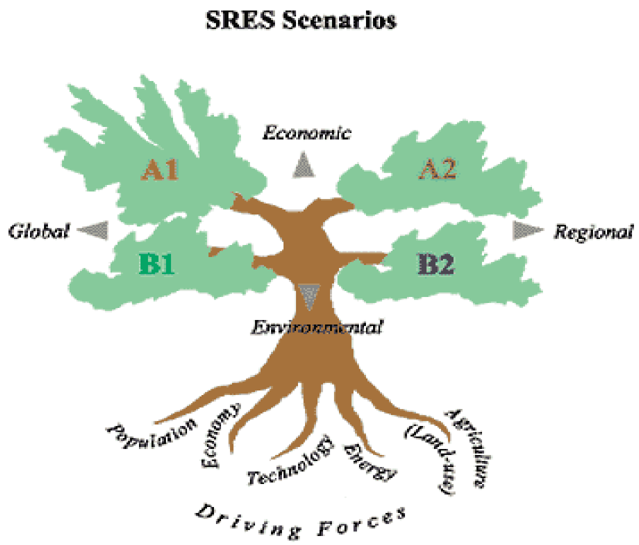


Figure 1 Schematic illustration of SRES scenarios. The four scenario "families" are shown, very simplistically, as branches of a two-dimensional tree. (IPCC, 2000)

A major issue in the application of climate change scenarios for an area the size of the state of Rajasthan has to do with the resolution in space of the scenarios. The state of most GCMs is that the resolution is in the order of several hundred kilometers. Recently, these models are improved so that the spatial resolution is finer as well, but these results are not yet reported and will not be treated in this report. The coarse resolution of GCMs makes it difficult, though not impossible, to assess future climate change in Rajasthan from the models. IPCC AR4 provided therefore only projections of climate change for a larger region in South Asia (SAS). Next to the spatial issues, the IPCC 4AR underlines also how the spread in projections of hydrological changes is still too large to make strong statements about the future of tropical climates at regional scales (Christensen et al. (2007)). Given these shortcoming IPCC came up with the prediction on precipitation for the 21st century (Table 2). From these predictions it is

Table 2 Predicted precipitation change (%) for the next 100 years for the South Asia Region (A1F1 and B1 emission scenario), note that A1F1 is the fossil intensive emission scenario of the IPCC

	2010 to 2039		2040 to 2069		2070 to 2099	
Season	A1F1	B1	A1F1	B1	A1F1	B1
DJF	-3	4	0	0	-16	-6
MAM	7	8	26	24	31	20
JJA	5	7	13	11	26	15
SON	1	3	8	6	26	10

expected that precipitation will decrease in the dry months of DJF and will increase in the monsoon period. In the SAS region the precipitation increment will be more pronounced than in the rest of Asia. Precipitation figures are expected to increase, with a decrement of 5% in the winter period and an increment of 11% in the summer period. Results with a moderate-resolution GCM (1.5 x 1.5 °) showed that the shift in more intense rainfall events is due to the northward shift of monsoon circulation (Christensen et al. (2007)). A major source of uncertainty in the area is the influence of the El Niño Southern Oscillation (ENSO) on rainfall in the South Asia region. These figures are only estimates for the South Asia region, but are of limited use for Rajasthan and to answer the more local questions posed in this project. It is, therefore, at this moment of time essential that Climate Change scenarios are downscaled to a state level and even to a city level. This asks for special techniques and datasets developed within other projects which are coordinated by Alterra – Wageningen UR.

The application of climate change scenarios in policy also needs attention. There is a discrepancy between the timeframe at which policy makers want information for and the accuracy at which climate models can deliver information. Policy makers generally want information at maximum for the next 10 sometime 20 years. They also want accurate climate change projections for these time frames. However the current state of the art climate science is not able to deliver that information. In recent scientific articles (e.g. a recent Nature overview article titled "The Real Holes in Climate Science") it was noted that "planners should handle them (regional climate projections, ed.) with kid gloves" and "All the problems, however, do not make regional simulations worthless, as long as their limitations are understood." The result presented in the last IPCC report and the models used for that are suitable to make climate change projection at 50 to 100 year timescales. At shorter (decadal/10 year) timescales the initialization of the models becomes very important especially the sea surface temperatures. Data on sea surface temperature is still scarce and as a result it is difficult to properly initialize the models. Therefore model outcome are not reliable for the near future and become much more reliable for 2050 when the increased greenhouse gas concentrations become the main driver within the system. Similarly, when no change is observed in one or a few climate change scenarios for 2030 it cannot be assumed that climate will not change for that period it also does not mean that climate will change but it is often better to look at the period beyond 2050 and backcast from there. It must be noted that there currently is a large scale initiative in the climate science community to improve decadal predictions.

Global Climate Change Scenarios

It has already been mentioned that the IPCC scenarios are very coarse for the application that is needed within this project. Figure 2 shows an example of a variable field from the ECHAM5-MPI-OM model and from the CRU_TS3.0 global observation dataset for the northern part of India.

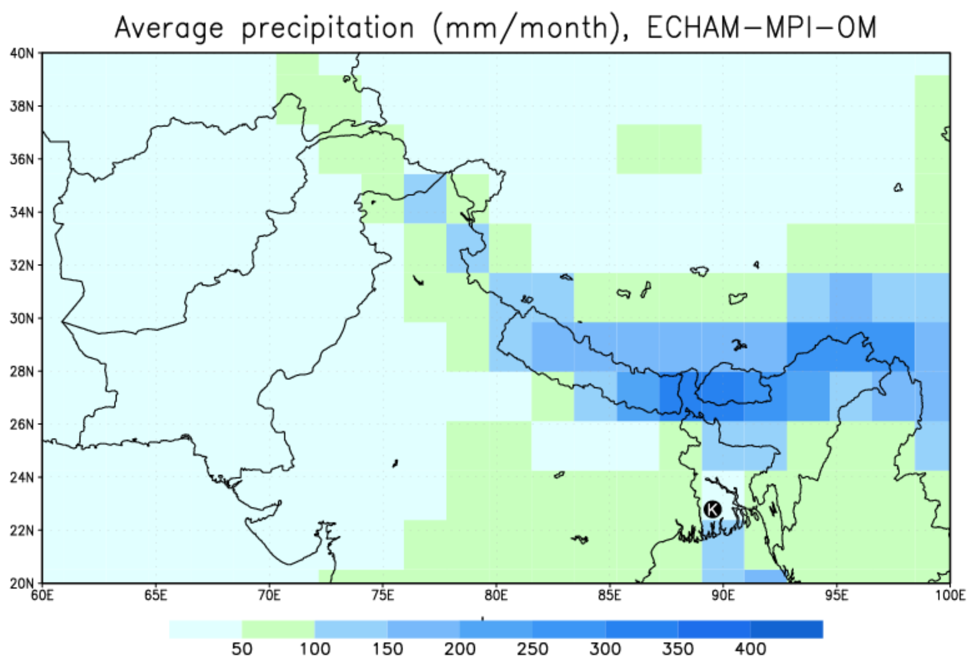


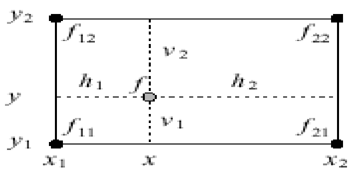
Figure 1 Monthly-averaged precipitation sum (mm/month) for 1901-2000 from the ECHAM-MPI-OM model.

The representativeness of the IPCC scenarios for an area in the vicinity of Anantapur is limited by the resolution which is used by the models. Also, the performance of each AOGCM (Atmosphere-Ocean General Circulation Model) is different per region of the world. The scale mismatch of the large scale climate models and the more local scale is, amongst others, addressed in the EU-funded FP6 (Sixth Framework Programme) Integrated Project WATCH. This project brought together “the hydrological, water resources and climate communities to analyse, quantify an predict the components of the current and future global water cycles and related water resources states; evaluate their uncertainties and clarify the overall vulnerability of global water resources related to the main societal and economic sectors.” (http://www.eu-watch.org). Workblock 3 of this project will produce multi-model based projections for the terrestrial components of the global water cycle for the 21st century. The advantage of this projection compared with the IPCC scenarios is that the resolution is finer (0.5 x 0.5 º) and that the different projections are bias corrected. The method of bias correction is explained in the next section and is adopted from the WATCH project. These finer scenarios are based on two SRES-scenarios: A2 (“business as usual”) and B1 scenario (“sustainable path”).

Climate Scenario Development

To assess the quality of the Climate Change scenarios it is of great importance to perform a comparison between output from the climate scenarios and the actual observations especially when Climate Change scenarios are developed at a more local level.

The WATCH climate scenarios are used to obtain projected time series of temperature and precipitation for 2040-2080. The time series are created by interpolating WATCH climate scenarios to the station location. The interpolation routine used is the bilinear interpolation (spatial interpolation of function values) which is graphically explained in Figure 4. In this figure f_{11}, f_{12}, f_{21} and f_{22} represent for example temperature or precipitation on the WATCH and the point f represents a station to which the climate data is interpolated.



$$f(x_1, y) = \frac{v_1 f(x_1, y_2) + v_2 f(x_1, y_1)}{v_1 + v_2}$$

$$f(x_2, y) = \frac{v_1 f(x_2, y_2) + v_2 f(x_2, y_1)}{v_1 + v_2}$$

$$f(x, y) = \frac{h_1 f(x_2, y) + h_2 f(x_1, y)}{h_1 + h_2} = \frac{h_1 v_1 f_{22} + h_1 v_2 f_{21} + h_2 v_1 f_{12} + h_2 v_2 f_{11}}{(h_1 + h_2)(v_1 + v_2)}$$

where $f_{ij} = f(x_i, y_j)$.

Figure 2 Mathematical illustration of the bilinear interpolation technique

Results

Current situation

From the Agricultural Research Station at Anantapur (ARS Anantapur) a large dataset was collected with all kinds of various meteorological parameters. This dataset range from 1985-2010 and the precipitation dataset even ranges from 1969-2010. From this datasets it was decided to look at both temperature and precipitation as these variables are most important to assess climate change scenarios. Figure 3 shows the temperature observations and Figure 4 shows the precipitation amounts both recorded at ARS Anantapur. From the temperature figure we can observe a fairly constant average temperature over the last 25 years. The precipitation shows more variability with higher yearly sums occurring more frequently in the last period of the observational dataset.

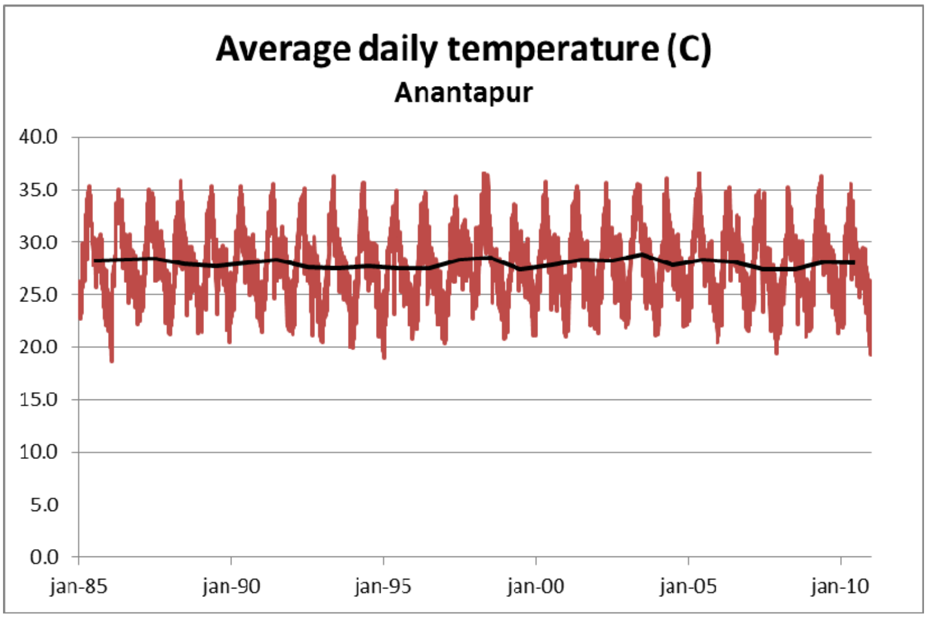


Figure 3: Average daily temperature (°C) at Anantapur (red) and the average yearly temperature (°C, black)

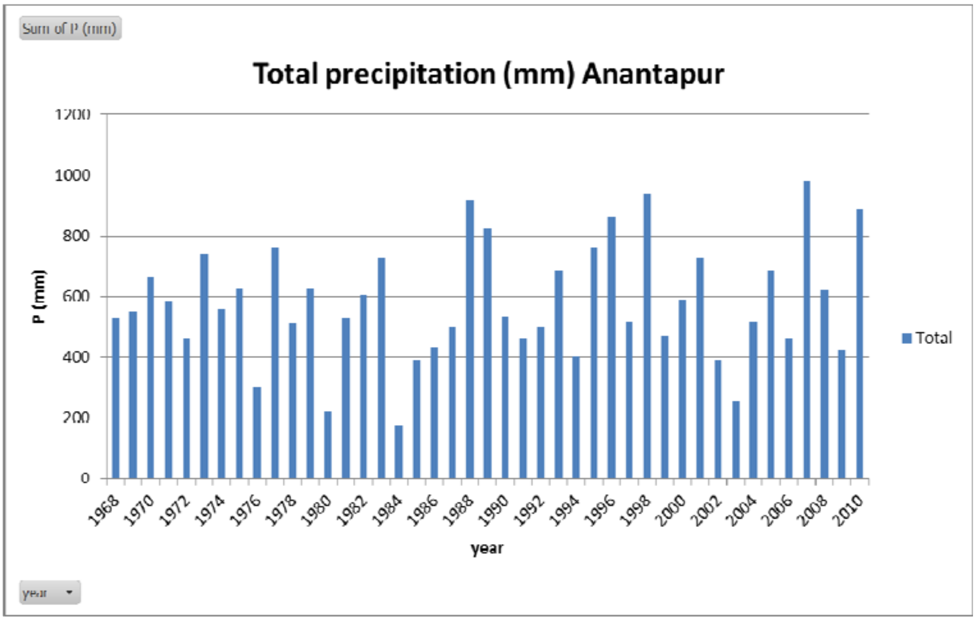


Figure 4: Annual precipitation sums (mm) at ARS Anantapur

Climate projections

The results shown in this paragraph focus on Anantapur. Figure 4 shows the projections of temperature for the three models and for an ‘ensemble’ of the models. This will be done for both emission scenarios A2 and B1. The ensemble is simply the arithmetically average of the three models per scenario.

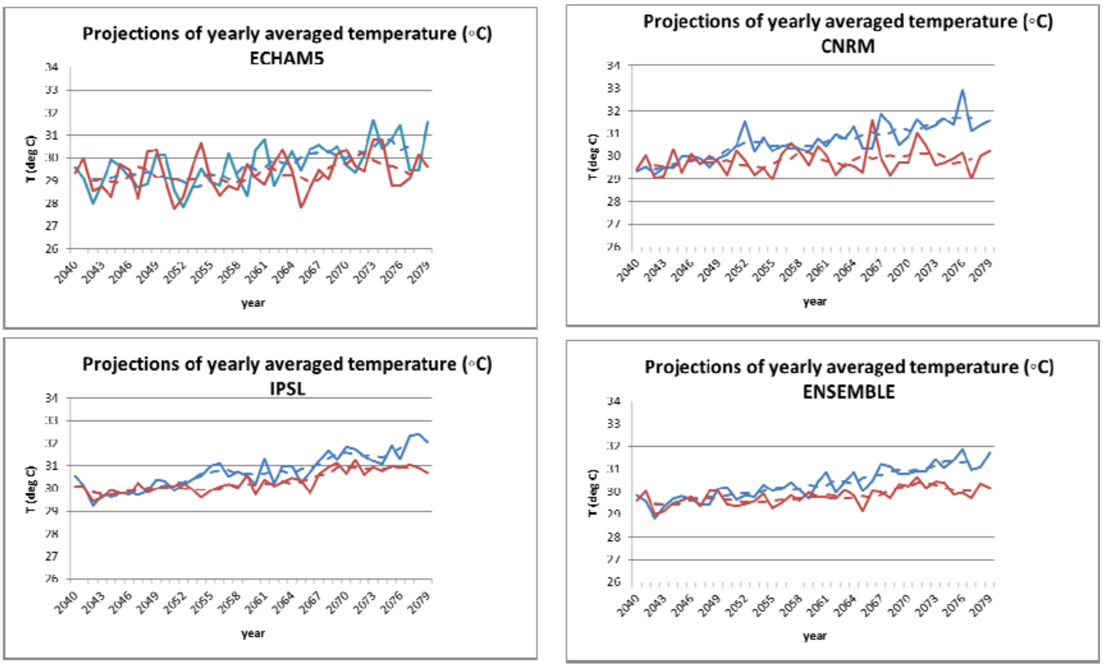


Figure 4: Projections of temperature at Udaipur for ECHAM (upper left), IPSL (upper right), CNRM (lower left), ensemble of models (lower right). Blue: A2 scenario (dashed: moving average of 5 years), light green: B1 scenario (dashed: moving average of 5 years)

While looking at the results for the downscaling experiment performed for Anantapur we can certainly see a trend in all models that the average yearly temperature is about to rise in the A2 scenario. In the (moderate) B1 scenario this rise is not so clearly seen and the model don’t agree. The IPSL model shows a rising trend in temperature of about two degrees in the A2 scenario between 2080 and 2040 and one degree in the B1 scenario. This model also shows the highest temperature for the area of interest. The ECHAM model shows a lot more variability between years and shows even a cooling trend in the decade 2070-2080 for both scenarios. The B1 scenario of the CNRM model shows a marginal increase in temperature. If we compare the projections with the observed temperature we can clearly see that the average temperature is clearly higher in the projections, regardless of the scenario or model used, than in the observations.

Table 3 shows a table with the maximum and minimum daily averaged temperature per 5 year period and for the growing seasons in these 5 year period. The growing season is defined from month 6 to month 12. This analysis is only executed on the ‘ensemble’ of the models for both A2 and B1 scenario. The extremes seem to increase stronger in the A2 scenario than in the B1 scenario. The maximum temperatures tend to cross 35 degrees at the end of the selected period for the growing season in the A2 scenario. This temperature is crossed already more frequent outside the growing season. This holds also true for the B1 scenario.

GROWING SEASON		ENS A2		ENS B1	
5 year period		MAX	MIN	MAX	MIN
2040	2044	33.91	23.03	33.43	22.81
2045	2049	34.55	22.78	34.14	23.30
2050	2054	34.28	23.23	35.27	22.66
2055	2059	34.28	23.48	34.28	22.66
2060	2064	34.99	24.41	34.31	23.26
2065	2069	35.07	24.29	34.77	23.68
2070	2074	35.65	25.20	34.49	24.52
2075	2079	36.63	25.44	34.92	23.77

WHOLE YEAR		ENS A2		ENS B1	
5 year period		MAX	MIN	MAX	MIN
2040	2044	36.44	22.82	36.57	22.81
2045	2049	36.21	22.78	36.75	22.75
2050	2054	36.96	23.23	36.50	22.66
2055	2059	37.95	23.48	37.57	22.66
2060	2064	37.64	24.41	37.41	23.26
2065	2069	37.49	24.29	36.89	23.68
2070	2074	38.18	25.18	37.77	24.52
2075	2079	38.88	25.32	37.30	23.77

Table 3: Maximum and minimum daily averaged temperature per 5 year period for both growing season (upper part) and the complete dataset (lower part)

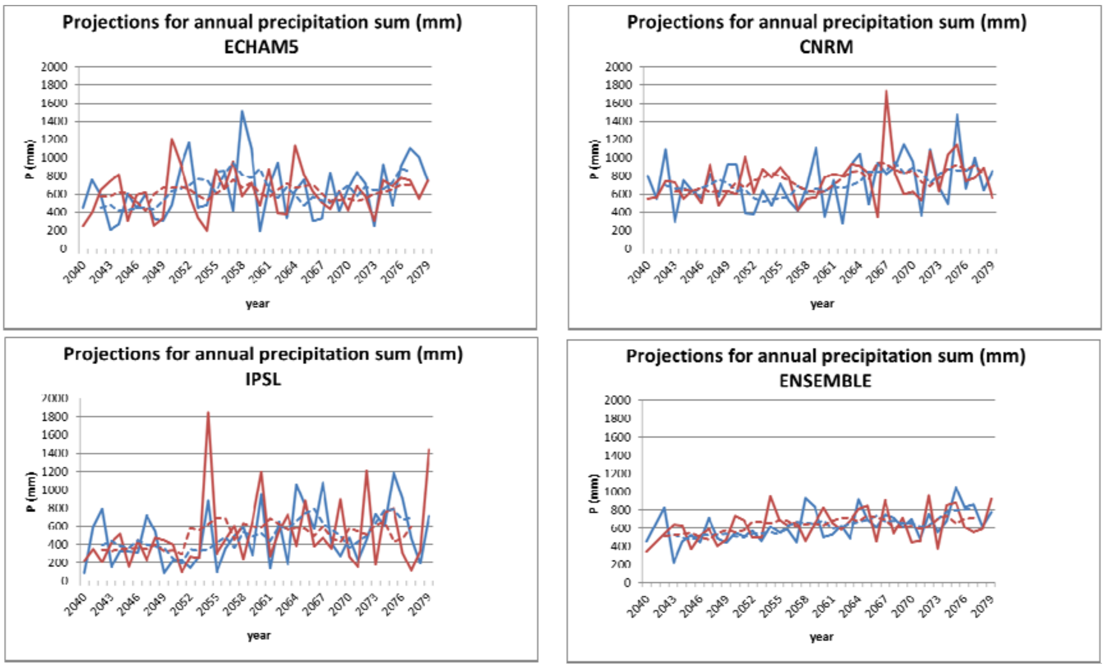


Figure 5: Projections of precipitation at ARS Anantapur for ECHAM (upper left), IPSL (upper right), CNRM (lower left), ensemble of models (lower right). Blue: A2 scenario (dashed: moving average of 5 years), light green: B1 scenario (dashed: moving average of 5 years)

COUNT(2040-2060)	EC_A2	CNRM_A2	IPSL_A2	EC_B1	CNRM_B1	IPSL_B1
p>50 mm	31	36	12	26	36	20
p > 100 mm	2	3	0	3	4	5
p > 150 mm	0	1	0	0	1	2
COUNT(2060-2080)	EC_A2	CNRM_A2	IPSL_A2	EC_ B1	CNRM_B1	IPSL_B1
p>50 mm	33	51	26	31	46	22
p > 100 mm	0	10	11	1	8	9
p > 150 mm	0	1	5	0	0	2

Table 3: Projections of count of certain precipitation events at Udaipur for all three climate models and two emission scenarios

Figure 5 shows the climate projections for annual precipitation at Anantapur. All models show an increase in precipitation between 2080 and 2040. The variability is high in all models and scenarios. If we take a look at the precipitation in the ensemble, it doesn't matter which scenario is used as both scenarios show the same kind of trend in the annual precipitation. The extreme events are not really visible in these graphs and therefore Table 3 is designed. This table shows the occurrence of a certain event per day in the climate projections. We have defined a daily rainfall sums of at least 50 mm as an extreme event. The period of 2040-2080 is split in two parts to show if a change is observed in the extreme events. We can conclude from this table that CNRM_A2 and IPSL_A2 show an increase in extreme events. The other scenarios show no change in extreme events.

Another important variable is the amount of rainy days in a year. This may say something about the duration of the monsoon season. Figure 6 shows the total number of rainy days per year. Per 5 year block an average is taken. We conclude that for all scenarios and model the number of rainy days per year will rise. The CNRM model tends to be wetter than the other two models. The conclusion of this analysis is that the monsoon period is more likely to increase with more rainy days and the days with heavy rainfall increasing slightly. However, more research is needed to analyse if the onset of the monsoon is earlier or that the monsoon is likely to last longer.

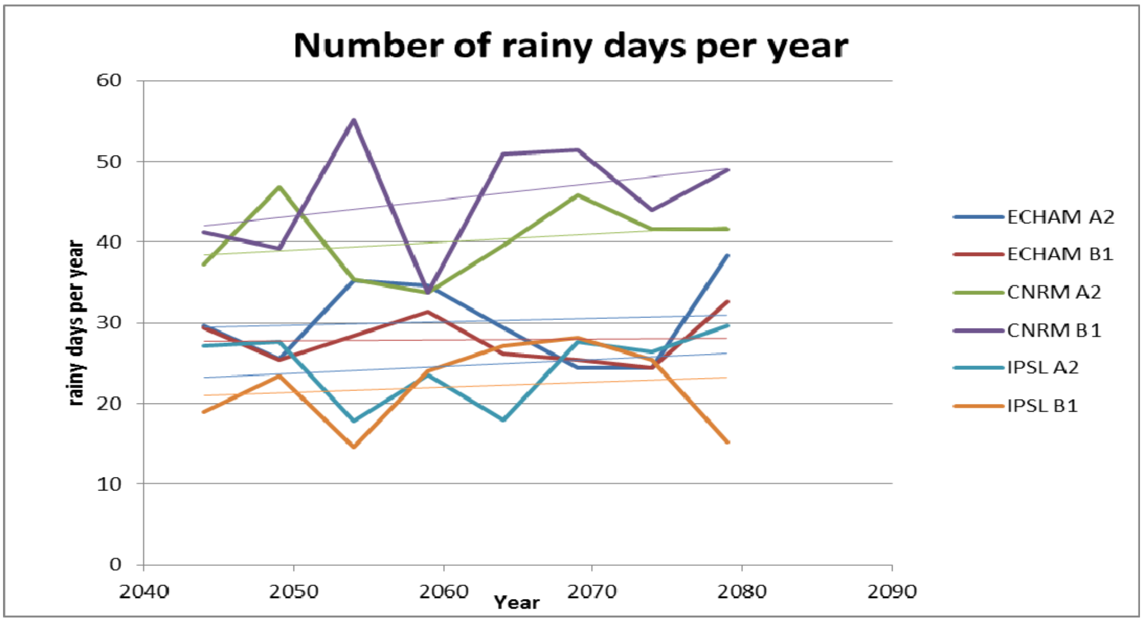


Figure 6: Projections of the number of rainy days per year (averaged per 5 year) for the various models and scenarios. The fine line is a linear regression per model and scenario

A remark has to be made about recent developments in the climate model. As pointed out earlier GCM’s are still running on coarse resolution. Recently, climate models are being developed which can run on a finer resolution (~0.25°) for a specific region. Within the EU-funded projects WATCH and Highnoon these, so-called, Regional Climate Models are run for the Indian subcontinent. As the spatial resolution is much smaller distinct features can be seen in the results resulting from, for example, topography or land-use.

Concluding remarks

The temperature show for all models a rising trend for both emission scenarios although the increase in the B1 scenario is only marginally. What is also clearly seen in the climate projections for precipitation is that the ECHAM model shows a lot of variability in the projections. Based on the data available at this moment we can conclude that it is likely that the temperature will rise, but that the magnitude of this increase is dependent on the emission scenario. The precipitation projections show an increase in annual precipitation with more rainy days per year and a slight increase of extreme events. Based on these findings we conclude that rainfall will fall over a longer period leading to a longer monsoon period. Some climate projections confirmed this hypothesis, but more analyses are actually needed to confirm this.

As the models have their own dynamics it is hard to assess a climate projection on its own without taking note of the other models. It would therefore be wise to include as much climate projections as are available. From the EU-WATCH project the bias-corrected output from the GCMs presented in this report are available. The next step in the evolution of climate projections is the generation of Regional Climate Model projections. Regional Climate Models are driven with output from a GCM at the boundaries. As their resolution is finer than a GCM it will give more regional detailed information. It is expected that the Fifth Assessment Report of the IPCC (AR5) will include more climate projections generated with these models. As more detailed information is available the hypothesis is that this will generate more realistic climate projections. Another positive point is that the climate projection will also be more tailored to the needs of users at a more local level. One of the disadvantages presented in this study is that the climate projections are still based on the coarse output which is generated by a GCM. However, it is the best that is out there at the moment.

Annex 3 Shade effects on microclimate and crops

(Iwan Supit, Wageningen University)

Introduction

Crop production may be at risk in the future due to increasing competition for water and increasing variability in temperature extremes (Rosenzweig et al., 2004). This may represent a vulnerability for many rural households that depend on rainfed agriculture for their livelihoods. According to Lin (2007), shade trees used in agroforestry systems offers an effective coping mechanism to implement in agricultural areas that suffer from climate extremes. This researcher mentions that temperature, humidity, and solar radiation fluctuations increase significantly as shade cover decreases and soil data showed larger fluctuations in soil moisture gain and loss in the low shade site respective of patterns of precipitation.

Overall, the amount of shade cover can be related to the mitigation of variability in microclimate and soil moisture for the crop of interest. The use of agroforestry systems is an economically feasible way to protect crop plants from extremes in microclimate and soil moisture and should be considered a potential adaptive strategy for farmers in areas that will suffer from extremes in climate.

The Anantapur situation

The introduction of agro forestry or agro horticulture as it is applied in the Anantapur region is a good adaptation measure against the increasing climate variability and higher temperatures. In literature not much is found about the optimal planting density of used trees, tree species and the type of crops that can be planted underneath the trees. Note that tree roots extract water also from deeper soil layers and the competition between trees and crops planted underneath is limited. Generally, the advantages are larger than the negative effects of water competition. To quantify to what extend the air humidity increases and the water requirement decreases as a result agro forestry/agro horticulture, more research is needed.

About the spreadsheets

The AnantapurA2 and AnantapurB1 spreadsheet can be used to estimate the effects of the increasing relative humidity on the potential evapotranspiration and the amount of water needed to obtain a maximum yield. The formulae underlying these spread sheets are derived from the FAO website (http://www.fao.org/docrep/X0490E/X0490E00.htm). Note that A2 and B1 stand respectively for the A2 (regional-economy) scenario and the B1 (global sustainable) scenario. In the A2 scenario the temperature increases stronger than in B1 scenario and consequently the potential evapotranspiration is higher.

By changing the section Temperature Increase and the section RH2 the effects of temperature increase and increasing relative humidity can be estimated. For example: Suppose that in the A2 scenario due to planted trees the field temperature increases 0.5 degree less and the relative humidity increases with 20%. Will reduce the potential evapotranspiration about 6% in winter and 13% during the South West monsoon. Note that in this example the changing wind speed as a result of tree planting is not considered. Under agro-horticulture conditions the wind speed will reduce and consequently the evapotranspiration will reduce.

Farmers confirm that shade of trees and alley plants has a moderating effect on the temperatures for the along the field crops. This can be related to the shade side of the trees as well as their transpiration. Trees also break the wind and might create higher humidity which lowers the evapotranspiration but may increase the chance on diseases.

Farmers are also aware on the effect of NPK on the drought resistance of field crops. If water is short for one week, field with NPK treatment will suffer after 5 days already, while manure application can stand upto 10 days. Manure is applied together with straw in a concentrated way in the tree basins and Alleys. Improvement on manures enrichment an straw for the fieldcrops could increase infiltration and water holding capacity of the soil.

Annex 4: Lay-out of agro-horticulture field plan

(S.A. Rahman, Accion Fraterna)

P	CS T P CS T	P	CS T P CS T	P	CS T P CS T	P	CS T P CS T	P
CS		G		G		G		CS
T		L		L		L		T
P		G		G		G		P
CS	<--20 m -->	P		P		P		CS
T		G		G		G		T
P		L		L		L		P
CS		G		G		G		CS
T		**Mango**		**Mango**		**Mango**		T
P		P		P		P		P
CS		G		G		G		CS
T		L		L		L		T
P		G	Slope --->	G		G		P
CS		P		P		P		CS
T		G		G		G		T
P		L		L		L		P
CS		G		G		G		CS
T		**Amia**		**Amia**		**Amia**		T
P		P		P		P		P
CS		G		G		G		CS
T		L		L		L		T
P		G	Slope --->	G		G		P
CS		P		P		P		CS
T		G		G		G		T
P		L		L		L		P
CS		G		G		G		CS
T		**Sapota**		**Sapota**		**Sapota**		T
P		P		P		P		P
CS		G		G		G		CS
T		L		L		L		T
P		G		G		G		P
CS		P	Slope --->	P		P		CS
T		G		G		G		T
P		L		L		L		P
CS		G		G		G		CS
T		**Custard Apple**		**Custard Apple**		**Custard Apple**		T
P		P		P		P		P
CS		G		G		G		CS
T		L		L		L		T
P	CS T P CS T	G	CS T P CS T	G	CS T P CS T	G	CS T P CS T	P

Legend

Fieldcrop

groundnut with 5 m contingency intercrop

Fruit trees

Mango, Amia, Sapota, CustardApple

Bio-mass trees

G=Glyricidea
P=Pongamia
L=Leucaena
CS=Casia Siamea
T= Prosaphis Juliflora (thorny plant)

---> slope directon

distance between
Alleys 20m
fruit trees 3m
Biomass 20 cm

Annex 4: Farm areas, production levels and prices

(B. Kondaiah, Accion Fraterna)

Sl. No.	Name of the crop	I st year 2008			II nd year 2009			III rd year 2010		
		Area	Production	Yield	Area	Production	Yield	Area	Production	yield
1	2	3	4	5	6	7	8	9	10	11
	Kharif									
1.	Rice	22	67	3017	30	95	3171	30	95	3122
2	Jowar	18	8	433	4	3	838	2	2	1237
3	Ragi	2	4	1816	2	4	2004	1	4	2519
4	Maize	4	20	4138	7	32	4323	6	21	3459
5	Red gram	26	4	135	37	17	467	34	13	386
6	*Groundnut*	*644*	*43*	*67*	*876*	*1102*	*1259*	*854*	*75*	*88*
7	Sunflower	27	10	359	19	10	525	20	9	428
8	Chillies	2	6	3226	2	9	4040	2	6	3498
	Total									
	Rabi									
1	Rice	11	32	2948	14	37	2576	18	49	2705
2	Jowar	25	15	619	12	8	624	13	7	556
3	*Bengal gram*	*84*	*31*	*368*	*75*	*78*	*1045*	*73*	*68*	*936*
4	Groundnut	18	19	1049	21	28	1307	17	25	1475
5	sunflower	34	14	411	26	20	751	23	18	794
	Total									

Table: production levels of crops in Anantapur District (Source: Hand Book of Statistics – Anantapur District)
(Area in '000 Hectares, Production in '000 tonnes and yield in kgs per hectare

Sale and input market: For the sale of agricultural production commodities, sufficient marketing facilities are available. The farm harvest prices of major agricultural commodities for the past two years is as follows in rupees per quintal (source: chief planning office, Anantapur)

Sl. No.	crop	Ist Year		IInd year	
		Kharif	Rabi	Kharif	Rabi
1	Paddy	885	787	1093	896
2	Ragi	774	--	860	--
3	Jowar	875	841	934	1044
4	Bajra	708	--	719	--
5	Groundnut	2167	2567	2117	2647
6	Onion	1060	617	1451	976
7	maize	614	634	874	759
8	Red gram	2024	--	--	--
9	Dry chillies	3666	--	--	--
10	Sun flower	--	2503	--	2341
11	Coriander	--	2256	--	2518
12	Bengal gram	--	2363	--	2373

Annex 6: Field visit report

Criteria for site selection of field visit

- Different physical area (soil type, topography, annual precipitation).
- Marginal, poor and dynamic farmers/ communities.
- Rain fed and supplementary irrigation.
- Application yes/no sustainable agriculture (Low carbon farming/organic farming)

Institutes at district level

- Departments for regulations and subsidies: horticulture, irrigation
- Agriculture university: Dry-land crops, horticulture

Visit report (and references)
Organised and guided by S.A.Rahman and B. Kondaiah

Wednesday 21/9,
Kuderu (mandal) Rijwana (A.T.L). Aruna, Socio technical organiser STO.

Site 1 Jayapuram (village): 77 km NW Anantatur, good AF village with 50% literate, 50% active women, irrigation group, 2 rain fed groups, labor group (from NREGA funds),.
Preparation of manure balls (Ghana Jeevamrutham): 1-week-old cow dung (1m x30cm), (2 cows produce 100kgs per week), 2 kgs pulse powder, 2 kgs jaggery (extract from sugarcane), one hand full soil, cow urine required for process of ball making.
One hour to make 200 balls of 500 gram wet weight; good for 25 trees (need 8 balls);
For row crops field application by hand spreading: seed at 5cms; 20kg powder per acre plus 100 kg farm yard manure (traditional); 1 dry ball is about 0.1 kg --> 200 balls.
For irrigation or spraying of jeevamruth: In 200 litres of water, mix 10 litres of cow urine, 10 kgs of cow dung, 2 kgs of jaggery and 2 kgs of any pulse powder, ferment it for 3 days before application.
Night soil is not used.

Meeting with about eight farmers: good introduction by Rijwana on Climate change.
Most water comes from deep bore wells, in Rabi half capacity. Drinking water from hills as part of Phanchayat program (2% fluoride in water).
Farmers experience on climate change: nowadays seasons are difficult to predict as weekly changes occur (cold, rain). Droughts trends: before one year on 4 years dry, now three years on 4years. Farmers give more water to cool/ reduce temperature (sic).
Farmers discussion on adaptation to droughts: 1/ efficient field irrigation and 2/ crop change, 3/ more water delivery by improvement in the watershed. In 2005 A.F. watershed programme handed over to the government and communities but maintenance of watershed neglected by the farmers.
Observation of temperature rise and more irregular rainfall with discussion on more shade (more story crops), deep-rooted crop, drought resistant crop, also keeping water in root zone by use organic matter and predominantly now: digging of individual farm ponds and wells.
Lunch close to Kudair office (long flat stone table)

Site 2 Karutlapalli, Field of 14-acre farmer (medium size) with plan for intercropping with mix tree and groundnut intercrop. He was installing an underground irrigation system from groundwater tubewell with government subsidy 90% if applied for introduction of drip irrigation. Actually used by less efficient surface irrigation. As slope is strong lanes could be better designed in contour with storm pits instead of on the slope; even better with drip irrigation.
Site 3 Programme wasteland development. Application for subsidy tree intercropping along flood plain on 4 neighboring fields totals 17 acres and 9 farmers (partly family). Compensation by AF is 5Rp for watering 1 tree (2x) per week. Location is very remote for transport harvest and for visitors.

Field risk flooding and does not serve biodiversity. Previous planting holes of earlier efforts were visible. Additional water from stream of irrigation area.

Thursday 22/9,
Darmavaram (taluk) silk city, 2 mandals, Rudraiah (A.T.L), Yerriswamy (STO)

Site 4 Two acre farm. Multiple cropping installed 2 year ago; nearby water pump of three brothers
Design: pigeon pea as intercrop of groundnut (Arachis hypochea). Border crop Bajra (pearl millet, sorghum) castor; The tree intercrop: 4 trees Mango, Amla, Sapota and Sithaphal, with biomass in row (Glyrecedia, Pongamia, Sesbenia, Casia Semia)
3 ways of planting were observed for comparison:
1. A small pit of 2x1x1.5 feet with the seedling positioned on a Rockwool for keeping the water available enriched with Jeevamrutham,
2. Plain seedling in a 2 feet cube pit with a well-established soil mix with Jeevamrutham. The seedling is supposed to establish as in nature (mother womb)
3. Farmers method of planting a seeding in a 3 feet cube hole with cow dung mixed with soil and after rain saturated with water. After two years, a clear different in development between the three systems could be seen in same sequence.
Maintenance under trees also manure and fodder storage, small horticulture. Azolla was cultivated in a basin, to provide N in bordering rice fields.

Discussion with three brothers under Tamarind tree close to a deep well. Before paddy was cultivated with hired labor; because water shortage they switched to rain fed farming. Now they have sufficient labor for the 2 acres a family. Farmers are forced to monoculture by government, but feel they better depend on their own strength; multi-cropping is better for system (water, nutrients, diseases, market prices) and for risk management.
Climate change effects were noted for temperature and rain: forestation is more robust and seems less dependable to rainfall deviation over years, months and weeks. Plantation is also economic. Used compost since 2 years. In vegetable-garden close by always manure is used.
Climate change proof of organic farming
Trees shade and transpiration keeps microclimate of crops cool; compost avoid water holds the water in the root zone and provides nutrients and bioactivity; chemical fertilizers 'double the heat' and binds water is soil. In vegetable fields if water is short for 7 days with fertilizer it is felt already after 5-6 days with compost only after 8-10 days. Use of compost increases the groundnut production from 20 to 25 bags per acre.

Site 5 New lands along the road. Several spots of retarded and nil growth in newly reclaimed land after land leveling floodplain along the road.
Large scale farm investment to create farmland out of flood plain causes:
1/ flooding problems, 2/ cut of fertile soil and 3/ loss of biodiversity.

Site 6 Palabavi
In this community under AF responsibility of Rajeswari (STO) and Shireesha (trainee STO), there is a strong women group. We met 16 to 24 people (2 men only) under a shelter (Peerla Chavidi) to discuss Climate change effects:

Water: before rains were regular in monsoon, now sometimes a week dry. Droughts resistant crops like sorghum and millets like pearl millet (Bajra), with 45 varieties. Till 10-20 years ago people practice mixed cropping: some always survived. Now groundnut is cultivated as cash crop in monoculture (20%) or with contingency crop like cowpea (80). Before local tanks were always full after monsoon, now they remain dry. Drinking water comes from a tube water system of Panchayat.

What to do if groundnut is short of water? Switch to other crop. All farmers use plain manure in the field. It replaces mineral fertilizers because low cost and serves low carbon programme. Farmers experience that manure holds water better in the root zone. Farmers are used to apply not enriched manure 5 tons/acre (10 cart loads) once in 3 year from 2 cows, enough for 3 acre.

Temperature: higher, bad feeling. Good to have two trees in the field for coolness. Big trees like Tamarind and Mango are good for shade and fruits. More but smaller fruit trees would be good for divers product and micro climate for plant production soil and income.

There is a micro-credit revolving fund programme for obtaining a cow with Rs 8000 credit and Rs. 2,000-4000 own contribution to reach the market value. This is interesting as after a half year, the amount has to be paid back. In the mean time 80-100 Rs/day can be earned by selling the milk, totaling to15.000 Rps (Rahman) .

Friday 23/9, Anantapur close to Devararakonda (God's hill), Agricultural Research centres under Acharya NG Ranga Agricultural University, Hydrabad under ICAR (Indian Council for Agricultural Research).

Site 7 Agricultural Research station, Rekulakunta (NE 12 km from Anantapur). Ravendra Reddy (head). Total area 82 ha. Cultivated 40 acres.
Fruit trees; priority to plant trees with higher density. Double or triple crop farming in line, keeping trees low and small by pruning to avoid dominance and facilitate harvest.
Arid fruit trees are: Custardapple, Mango, Ber, Pomegrante

Also experience with forest in watershed harvesting useful fruits: Alovera (medicine)
Intercrop experiments as contingency crop (in case failure main crop): red gram, cowpea, Castor (oilseed)

Mechanisation section and droughts: If late rains groundnut planting possible with water: two drums 500 l each, 1,2m2 6 rows, for 1000m2 in row: 1 mm or per row (2.5 cm/30cm -->) zero, 4 mm equivalent.

Meteorological station: at 558 m ASL. Observations from 1968 onwards and collect measures from 63 mandals.
Measurement of 8 parameters (class B station)
-Temperature wet/dry bulb (humidity), Min/Max Soil temperature at 5-10-20cm deep
- Wind speed and direction. Two monsoons are observed: summer strong SW wind from June to August, then NE winds from October to December.
- Rainfall daily, automatic (writer) and special disaster rainfall observer for showers<1 hrs.
- Sunshine (4 season-cards)
- pan class A
- Dew gauge

Legislation for groundwater use for irrigation from deep wells: Land and water act determines the distance and depth; state provide 90% subsidy department of Horticulture 70% There is no groundwater research, only pump tests on productivity of well. Or more information Dr Reddy, Dr. Narasimha Rao.
Labor requirement for field crops: only station data available 10 labors for 40 acre.
For horticulture data Fruit Institute is at Hydrabad. There is a growing need for labor on market.

Manure: number of cattle goes down. According to Rahman no problem as sustainable farming need only one cow for 30 acres if Jeevamrutham and fodder is used. But may be more manure is needed is mulch for root zone is included keep water to protect from heat.
Trials with less nitrogen application: 100, 75, 50 % N applied to avoid overdoses for cost and environment.

Site 8 Agriculture Demonstration Farm Krishi Vignan Kendra, Reddipalli farm (15 km NE of Anantapur)
Has 10 acres paddy and dry crops and exists 30 years,. Dr.P. Lakshmi Reddy (programme director)
Fertilizer doses advised doe rice: 20kg N/ha, already sufficient P and K in soil. And for rain-fed crop: 6kgN and 16kgP.
Increased planting densities of Mango (6x8m) with intercrop groundnut or if late rains horse gram.

Discussion with junior scientists from institute on:
Climate change impacts:
Rain changes: monsoon before July to Sept, now earlier and starts in June to August; also less rainfall which creates low humidity and less diseases.
Temperature increase; High temperature (45^o) resilient rain-fed trees Mango, Tamarind, Neem, Pongamia. High temperature resilient field crops: Castor, Horse gram Pearl millet, Jowar.
Sustainable agriculture
Tree competes with crop for space, water, shade. Trees may produce toxic for other crops.
High humidity of multi story crops may cause more diseases.
Drought: increased water holding capacity by use of organic matter. Who studies beak-down organic matter and temperature?
Number of cattle decreases
Labor cost per day 100+Rp/day
Government policy not to cut trees without permission.

Saturday 24/9, Kalyandurg (taluk; 60km SE,) Ecological Demonstration farm Kalyandurg(4 mandals), Kundurpi (100km SW Anantapur); Agriculture Officer: Naganna, STO: B. Yerriswami Reddy

Site 9 Situated 5km south of Kalyandurg, 2-acre farm with 1-acre field 4-type intercrop: field-, border-, inter- and trap-crop and 3 ways of planting.
Field crop: groundnut 30x10 cm; with alternatives, Redgram, Horsegram
Intercrop (6m each): 2 rows Green gram, 1 row of trees: Mango, Sithaphal (custard apple), Amla (Indian Goose berry), Sapota
Border crop for biomass like Foxtail Millet keeps also insects and dry wind away and
Trap crop: castor and cowpea against control of pest like Spodoptera and Helicoverpa
Planting methods trials similar like before): 1.5 feet hole and organic substance, 2 feet rockwool method (cushion), and 3 feet farmer method (seedlings and soil with compost only). A 1-acre reference field same crops (little organic matter 3 feet planting).

Site 10 Chintarlapalli (15 km from Kundurpi) 2,5 acre rain-fed farm (400-500mm/y), planted Horse gram instead of Groundnut because more drought/heat/wind resistant.

Crop	Rain-fall	Season (mths)	Prod (kg/acre)	Market price (Rs/100kg)	Total/acre	Prod costs	Profit
Groundnut	5-600	3-4	4-500	5000	20.000	5.000	15.000
Horsegram	4-500	3-4	5-600	2300	11.500	500	11.000

Site 11 Village meeting Kundurpi (20-40 farmers)

Climate change effects and impacts :
Now crops earlier dry because , higher temperatures and less rain. Before lower temperature and more rain possibly because more trees and multiple cropping,
Water table goes down because heat: before 100 ft, now 300ft.
Over dosage of fertilizer (20% farmers give too much)--> impact on environment
50 % of farmers use less than 1/3 of requirement -→ low production
Society:

Now also more pollution in the region because vehicles, factories,..
Market ask for more crop --> mono crop --> more fertiliser and diseases
Measures:
More trees in field makes cooler but compete with crop (roots, shade).
Multiple cropping is proper tool for risk management income.
Try to use rainfall better by contour, pits and improve water holding capacity soils , all use urea and manure in the field as fertiliser (but also for WHC and active soil live). Considerations:
More groundwater when more trees in watershed And less use(rs);
There was an S&W programme under AF in the past. Now neglected by community.
Naganna: NPK not advised as low carbon policy. Nearly all farmers use manure every year to all fields. If 10 cart loads (5 tons)/acre enough for 2-3 years. Only two have enough heads for the field: one acre need 4 head (in Palabavi, Darmavaram 2 head for 3 acres: 22/9?).
Apparently less attention for land and water: Task for Panchayat/ Ecology Centre? Short of manure for all fields; need purchases from outside. Supplementary cattle breeding is an option with fodder production and microcredit. Options Rahman: buffaloes, bullocks, cows, better than sheep and goat; for chicken too hot.
Lunch break at FA office at the foot of Kundurpi (hill of Goddess)

Site 12 Yeragunta village with an irrigated 12.5 acre farm full organic multilevel tropical fruit garden exists already for during 24 years of 2 families with 8 sons who will split soon. Labor input: 20 from family, 20 outside labors: 100-150 Rs/day plus 3 meals. 14 buffaloes (manure has to be bought in). Water is pumped 4 hrs/day from in total 50 m deep: a 30ft deep pit and 120 ft deepwell. Crops are: Arikanut, Coconut, Beetlevine, Pongamia, Tamarind, Gua, Vitax, Ber, Papaya, Banana, Jackfruit, Sithaphal (Cutard apple), Neem.

Observations: Along the road (25 km from Anantapur) Citrus plantation with drip irrigation. Planting along contour with pits between the trees and a bund line at the lower end for run-off water and litter collection.
In Kalyandurg intensive network for drinking water (1 feet pipeline along the (newly paved) road and pressure towers newly constructed on initiative (grama Panchayat). Also 3 feet pipeline and regular off-takes for drip/ sprinkler from (subsidized private deep wells 30-60 feet deep).

Monday 26/9, Anantapur

Site 13 Watershed section AF Ecology Centre, relevant for role of trees and the soil and water conservation in the watershed B. Lakshmi Kantham, before 34 years in government service and at AF since 2008. Forest protection area covers 1.93 lakh ha or 10% of Anantapur, of which now 2 % is still green.
Forest rehabilitation
Since last 50 years many trees have been cut; soil is exposed to sunshine and rainfall --> less soil quality and erosion and vegetation quality. Forest fragmentation with relative many boundaries aggravates this problem especially for wildlife. Area is fenced and only open to Forestry staff (Forestry Act); however, as area is too vast for soon rehabilitation, communities are allowed if there is an agreement with the Village Conservation Committee (VCC)/ Village Protection Committee (VPC) sharing investments and fruit use. Also, use of high income trees like Mango and Amla. AF is still working in some watershed areas, for example, 250 ha degraded forestland with interventions: soil and water conservation, tree planting and 5-10 yrs maintenance. According agreement farmer may collect and keep 50%. Revenue land is distributed in plots of to 2 acres at regular intervals to landless farmers according ‘patta’ (right on land). These areas are dispersed and difficult to control and manage.
Climate change
-Rainfall: rainfall always between 500-550 mm. Rain distribution depends on the SW and NE monsoon; less number of rainy days: before 45 to 60 rainy days. Rainfall has become more intensive resulting in water loss by runoff erosion and sedimentation and increase of no-rain days resulting in drought intervals.

-Temperature rise
In forest, deep-rooted crops are heat resistant: Neem, Pongamia, Ficus, Acacia. Shallow rooted trees like Carisa Carante and three others have become extinct. Droughts resistant plants take over like euphorbia (they have thick cortical on stem) but with high fire risk.
-Role of trees in agriculture land
Trees are useful in agriculture area as fodder, firewood, fruits, litter, timber, shade, positions preferably at the boundary of the field; Biomass of tree can function as fertilizer and increased water holding capacity. Trees have no negative influence on water for crop roots as deep rooting (deeper than 6 feet). Roots even have tendency to release some water into the soil (check). No competition for place and shade if trimmed. Trees provide N through the fallen leaves (litter) about 200kg N per year by 100 border plants.
-Mango best use as border crop or main crop (6x6, 8x8m). For us in line Mango can be trimmed up to 8-10 feet high and 10 to 15ft wide. Harvests reach 4-15 sacs during 50-70 yrs.
Border crops good for biomass are Neem, Ficus, Jamon, (blackberry), Pongamia, Accacia, Sesbenia. Field crops like groundnut only the first 5 years as inter crop of Mango. Financially Mango plantation is most interesting for farmers: less risk, less labor, rain fed, irrigation production effective.

Crop*	Mango 8*8	Mango 8*16	Field crop	Labor	Rainfed crop
Rp/yr/acre	35.000	17.000	17.000	7000	Rps 10.000

* 7000/acre Rps for labor or 70 days/yr

Fruit trees are picking up in the district with investments form NREGS (National Rural Employment Guaranty scheme). Experiments on irrigated high density plantations with 70, 100 to 200 plants per acre which may give 2 to 3 time-fold yield and very little diseases when use of bio pesticides and bio fertilizer Jeevamrutham.

Site 14 Raminepalli, rice experiment (15km South of Anantapur)
AF has set-up an experiment by Mr. Kondaiah to measure the release of greenhouse gases CH4, N2O and CO2 under 3 different management regimes on half acre plots:
1/ application of the formal main stream practices with urea, chemicals, double seedling planting, regular irrigation;
2/ sustainable agriculture practices on double seedling planting, like liquid organic (jeevamrutham) fertiliser, azola and extended irrigation intervals;
3/ as under 2 but also single seedling planting as part of the system rice intensification (SRI).
Irrigation interval, daily water level, rainfall and temperature (min/max) are measured.
For the trial the production of CH4, N2O and CO2 of one plant is collected in a multiplex cube and a sample is taken daily for analysis in the laboratory at the Ecology Centre. In cooperation with five other organisations the data are processed and compared with standard production of GHG in rice fields.

Tuesday 27/9, Anantapur

Site 15 Ecological Centre Accion Fraterna
Interview with Mr. Vidya Sankar (Assistand director Horticulture department, Anantapur district) and Mr. Sambasivarao (Junior director Agriculture Department, Anantapur District)
Competition between trees and other crops exist also when horticulture is drip irrigated.
For space orchards in general 7-10 m distance. First 4 years intercrop of pulses, vegetables is done.
Now experiments with Pomegranate, Ber, Gua, Amla, Mango from 40 to 70 plants/acre all under irrigation.
Competition at multiple cropping like in AF approach, can be avoided by 1/ trimming of trees, 2/ field crop at least 3 m from stem, 3/ additional water storage in rootzone at various layers. Drip irrigation keeps roots short and makes crops less drought resistant.
Concern on withdrawal groundwater
Policy on promotion drip irrigation only for farmers with less than 5 acres: SSSR

A.P. Water Land Tree Act: permits only for deep wells at more than 200m distance with details on water depth, capacity, hours, and payment. More information at Groundwater department.
Labor input for horticulture crops:
Perennial crops like Mango: five labors/ acre, for seasonal crop about 10 labors/ acre, month

Annex 7 : Useful definitions

HALICUT / ANICUT: low and wide dams built of flat-stones. It slows down the water flow of a stream (NALA), facilitate infiltration water to the groundwater and sedimentation toward valley terraces. Farmers are generally allowed to construct them till 2 m high at a max.

LAKH represents the number 100.000. in the sequence 10, 1000 etc.

KHARIF, 1st season, monsoon period, summer (autumn), variable duration between May-October with crops: millet, paddy, maize, pulses, groundnut, red chillies, cotton, soybeen, sugarcane, turmeric.

NREGA: (National Rural Employment Guarantee Act) public work to create infrastructure and provide income in rural areas. NGERA implemented through the District Rural Development Agency provides 100 rph per family for 100 days/yr = 10,000 per year max as social minimum.

RABI, 2nd season, winter with crops: Wheat, Barley Mustard, Peas, Oats, Kadli.

SARPANCH drinking water tanks bringing water into the Hamlets (fala) in periods of water shortage.

ZAID, 3rd season with crops: water melon, musk melon, cucumber, vegetables, fodder crop.
Rabi and Zaid crops are mostly irrigated.