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Presentation ON

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A Lecture
ON

Implications of Agroforestry systems/Practices in the arena of Climate change for the Enhancement of farmer's Income

Speaker

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Contents

Why doubling the farmers income?

- **Agricultural contribution to GDP is comparatively less and reducing over a period of time from 23.4% in Ninth Five Year Plan to 15.2% in Eleventh Five Year Plan.**
- **Rapid growth is very necessary to attain inclusive growth since a major source of livelihood of majority is Agriculture in India.**
- **Employment share of agriculture has been reduced from 64.8% in the year 1993-94 to 48.9% in the year 2011-12 (CSO).**
- **There is a vital need to look at agriculture in terms of source of livelihood for a major portion of the community, instead of mere productivity.**

INTRODUCTION

DFI Concept and its evolution:

- **Inception:** Our Hon'ble Prime Minister Narendrabhai Modi expressed his desire of **doubling farmers' income** (DFI) by the **year 2022**, while addressing a farmers' rally in Bareilly, U.P., on February 28, 2016.
- **Base Year:** Doubling farmers' income (DFI) of the agricultural year 2015-16 by the agricultural year 2022-23.
- **Required agril. growth rate:** For DFI in 2022, an annual growth of **10.46 per cent every year** (2016-2022) is required, (whereas, agri. growth rate was at 1.80 % in 2015-2016).
- **What is sought to be doubled?** The income of farmers, not output or value added or the GDP of the agriculture sector.

Source: Chand (2016)

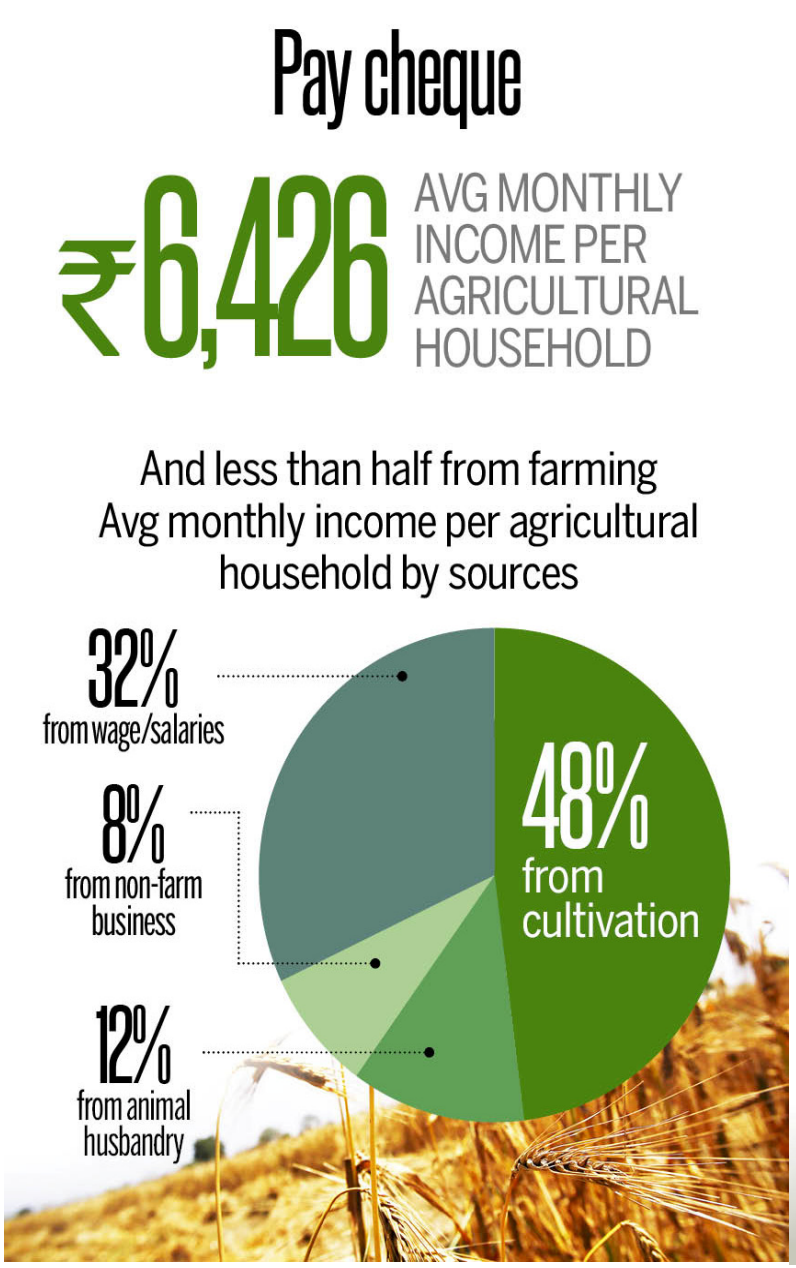
Approach for doubling farmers' income

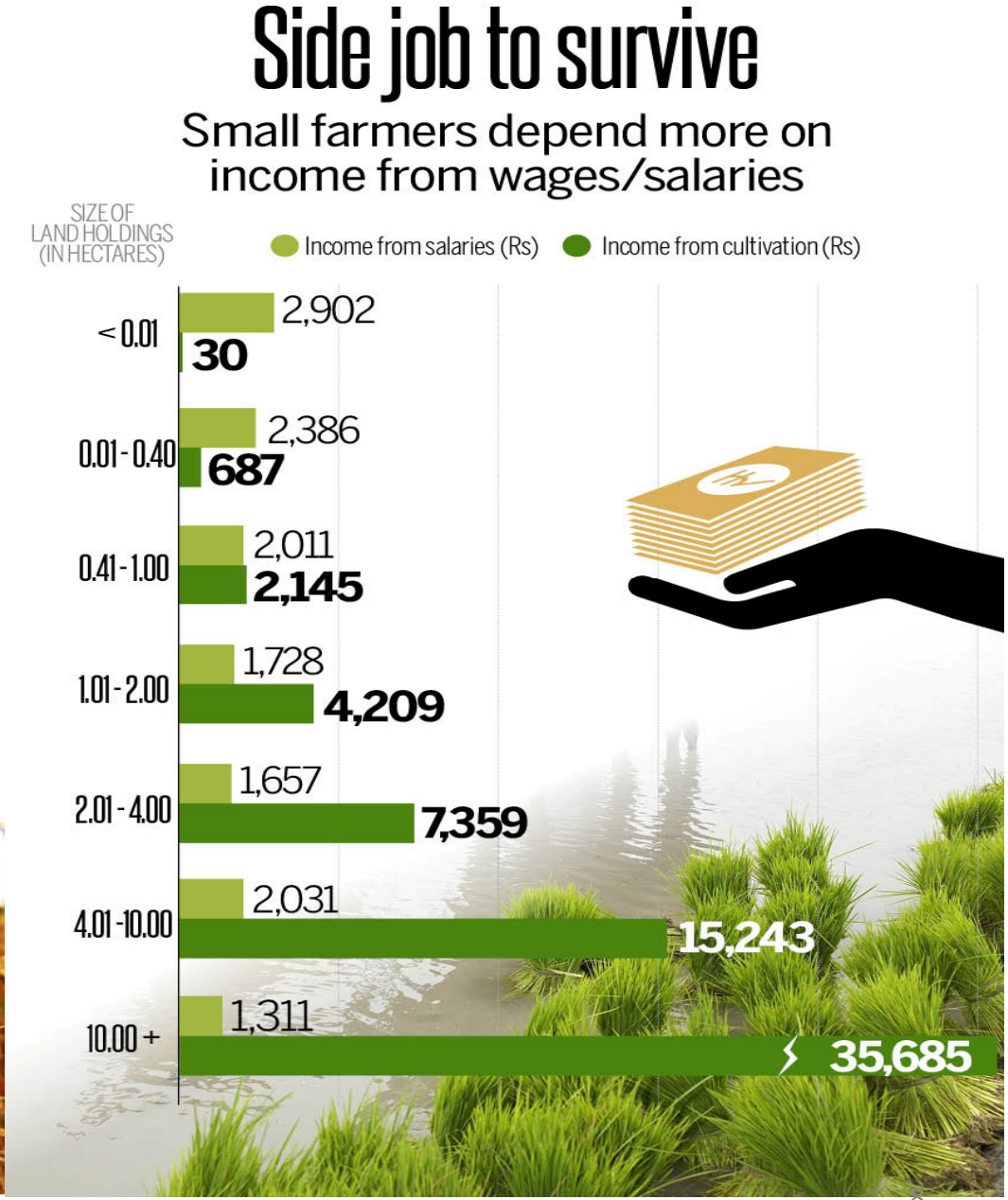
Strategies	% increase in farmers' income
Govt. policies and Development of Infrastructure	30-35
Productivity improvement	30-35
Cost optimization	10-20
Value addition & Minimization of PHL	20-30
Promotion of ancillary activities Poultry, Beekeeping, Goat rearing, agroforestry and fisheries	10-15
	100

Current Approaches for measuring farmers' income:

- The mission of doubling farmers' income requires **accurate information** on certain indicators which reflect the farmers' income and welfare.
- For **accounting farmers' income**, past studies have largely used data regarding growth in agricultural output (VOP/AgGDP/GSDP), output and input price behaviour along with price spread, rise in wages and rising indebtedness, using:
  - **Farm business income from CACP data**
  - **Aggregate and disaggregate farm income using CSO and NSSO data**
  - **Income purely on the basis of Situation Assessment Survey of NSSO**

Average monthly income per agri. household in India





Source: NSSO (2014)

Growth in per capita monthly agri. income between 2003-2013

- The average monthly income per capita from farming increased from **Rs. 1,060 in 2003 to Rs. 3,844 in 2013.**
- Compounded annual income growth rate (CAGR): **13.7%** → nominal (numerical) terms, without taking inflation into account.
- DFI by 2022: **15% CAGR is required (nominal).**
- **But to increase the income in real terms would imply restructuring agriculture processes & policy interventions.**

Source: ICFA (2016)

Real Income or Nominal Income?

- Income is of two types: Nominal (with inflation) and **Real (without inflation).**
- Thereby, if inflation in agricultural prices is high (in nominal terms) farmers' income will double in a much shorter period.
- **Twice over the last 30 years, farmers' income at nominal prices almost doubled in six years** — once between 1987-88 and 1992-93 and then between 2004-05 and 2009-10.
- In current price terms, value added per worker in agriculture has increased by **28 times** between 1980-81 and 2014-15.
- But in constant price (real) terms, value added per worker in agriculture increased **1.8 times** between 1980-81 and 2010-11.

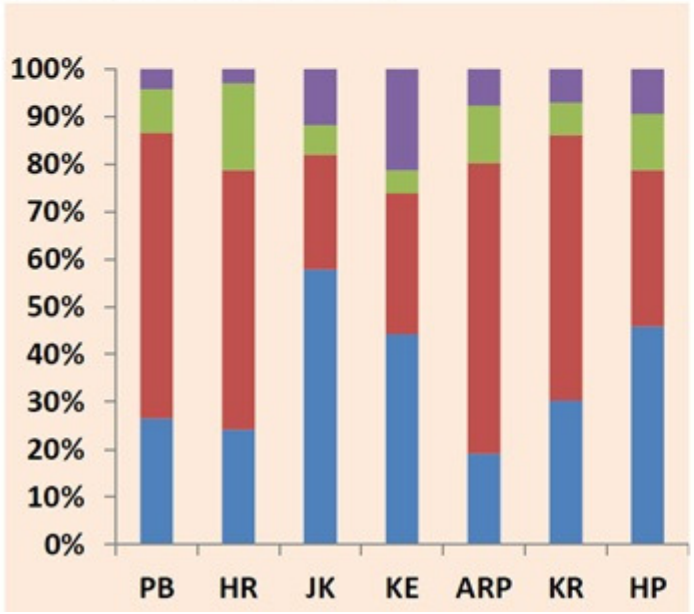
Source: NSSO (2014)

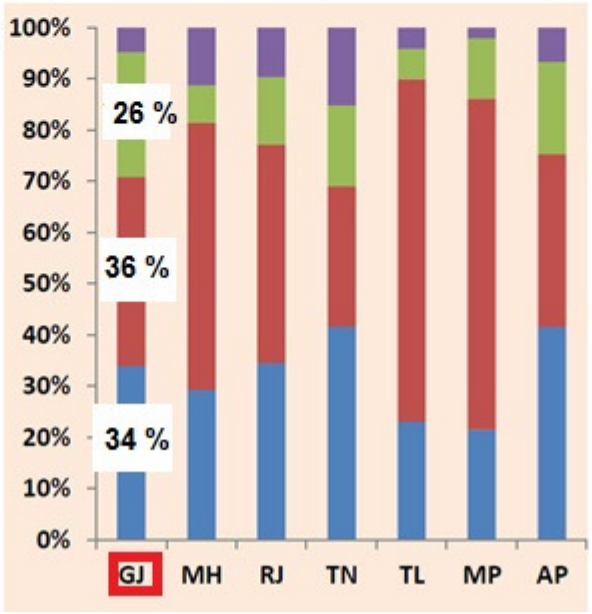
Sources of average monthly farm Income (2012-13)

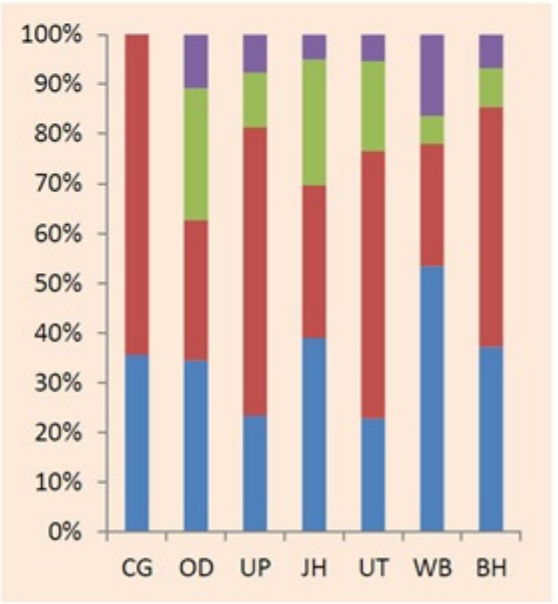
Category I States	
Punjab	18059
Haryana	14434
Jammu & Kashmir	12683
Kerala	11888
Arunachal Pradesh	10869
Karnataka	8832
Himachal Pradesh	8777

Category II States	
Gujarat	7926
Maharashtra	7386
Rajasthan	7350
Tamil Nadu	6980
Telangana	6311
Madhya Pradesh	6210
Andhra Pradesh	5979

Category III States	
Chhattisgarh	5177
Odisha	4976
Uttar Pradesh	4923
Jharkhand	4721
Uttarakhand	4701
West Bengal	3980
Bihar	3558







Net receipt from Non-farm business

Net receipt from livestock

Net receipt from cultivation

Income from wages

Source: NSSO (2014)

Past performance of income growths

- Doubling of real incomes by 2022-23 would require a compound growth rate of 10.46 per cent per annum.
- **Possibility: Madhya Pradesh has registered 14.2 per cent growth in real agri-GDP between 2008-09 to 2014-15.**
- Gujarat, Jharkhand, Chhattisgarh, H.P., Rajasthan, and Bihar have witnessed agri-growth in excess of 7 per cent.
- **During 1978-86: China's farm incomes** grew at 14 per cent per annum and agri-GDP at 7.1 per cent.
- **China's performance: Agri-growth in China** helped the country to halve its poverty in just six years. It generated a huge demand for industrial products in rural areas, which were met by scaling up town and village enterprises (TVEs).

Source: Sardana (2016)

Farm-wise income growth during the last decade (2002-03 to 2012-13) in India

Size class of land possessed (ha)	Total income (Rs.) / agricultural holding / annum		CAGR (%)	Real CAGR (%)
	2002-03	2012-13		
1. Landless < 0.01	**16560**	**54732**	**12.70**	**6.19**
2. Lower Marginal (0.01-0.40)	**19596**	**49824**	**9.78**	**3.27**
3. Upper Marginal (0.41-1.00)	21708	62964	11.24	4.73
4. Small (1.01-2.00)	29916	88176	11.42	4.91
5. Semi-Medium (2.01-4.00)	43068	128760	11.57	5.06
6. Medium (4.01-10.00)	68172	235644	13.20	6.69
7. Large (>10.00)	116004	496656	15.65	9.14
All sizes	**25380**	**77112**	**11.75**	**5.24**

Source: NSSO (2014)

State-wise level of Income (Rs.) and doubling time (years)

State	Avg. Income (Rs. / annum)		CAGR (%)		Doubling time in years @ given CAGR	
	2002-03	2012-13	Nominal	Real	Nominal	Real
Andhra Pradesh (AP)	19608	73392	14.11	7.19	5.25	9.99
Gujarat (GJ)	32206	95112	11.44	5.61	6.40	12.69
Jharkhand (JR)	24828	56852	8.60	2.94	8.40	23.93
Karnataka (KA)	31392	105884	12.91	5.71	5.70	12.48
Madhya Pradesh (MP)	17160	74508	15.62	9.81	4.72	7.40
Maharashtra (MH)	29556	88620	11.61	5.66	6.31	12.56
Punjab (PJ)	59520	216708	13.79	6.66	5.36	10.75
Rajasthan (RJ)	**17976**	**88188**	**17.24**	**9.39**	**4.36**	**7.72**
Tamil Nadu (TN)	24064	83780	12.91	6.88	5.71	10.72
Uttar Pradesh (UP)	19596	58944	11.64	4.72	6.30	15.02
All India (IN)	**25350**	**77124**	**11.76**	**5.20**	**6.24**	**13.56**

Source: Satyasai and Bharti (2016)

Prime Minister's 7 point mantra for achieving the goal of DFI

1. Big focus on irrigation with large budgets, with the aim of "**per drop, more crop**."
2. Provision of quality **seeds and nutrients** based on soil health of each field.
3. Large investments in warehousing and cold chains to **prevent post-harvest crop losses**.
4. Promotion of value addition through food processing.
5. Creation of a **national farm market**, removing distortions and e-platform across 585 stations.
6. Introduction of a new **crop insurance** scheme to mitigate risks at affordable cost.
7. Promotion of ancillary activities like poultry, beekeeping and fisheries.

Flagship schemes to achieve DFI goal

Coupling DFI goal with many new and well thought out schemes:

- *Pradhan Mantri Fasal Bima Yojana*
- e-National Agricultural Market
- *Paramparagat Krishi Vikas Yojana*
- *Pradhan Mantri Krishi Sinchai Yojana.*

Drivers of DFI:

1. **Diversification** of farm activities towards high-value crops and enterprises.
2. **Irrigation**, which can double productivity.
3. **Better price realization** for farmers through competitive markets, value chains and improved linkage between field and fork.
4. Improvement in the **terms of trade for agriculture.**
5. **Technology up-gradation**.
6. Making farming **less labour-intensive.**
7. **Shift of cultivators** from farming to non-farm occupations.

Increase in yield due to drip irrigation over surface irrigation

Crop	Yield, kg/ha		Yield increase	Increase in income(Rs./ha) due to drip from increased yield
	Surface	Drip	%	
Cotton	3266	3637	11	18550
Sugarcane	112000	130000	16	36000
Brinjal	33000	46000	39	32500
Banana	77000	97000	26	60000
Castor	2400	2670	11	8100
Papaya (Tiwan-786)	26000	32000	23	12000
Water Melon (Red Hunny)	12484	14195	14	111215
Turmeric (Sugandham)	21570	25370	18	38000

Strategies to increase the income of the farmers

Hon'ble Prime Minister of India Shri Narendra Modi has envisioned seven- point strategy to double the income of farmers by 2022.

- **Big focus on irrigation with large budgets, with the aim of "per drop, more crop."**
- **Provision of quality seeds and nutrients based on soil health of each field.**
- **Large investments in warehousing and cold chains to prevent post-harvest crop losses.**
- **Promotion of value addition through food processing.**
- **Creation of a national farm market, removing distortions and e-platform across 585 stations.**
- **Introduction of a new crop insurance scheme to mitigate risks at affordable cost.**
- **Promotion of ancillary activities like poultry, beekeeping and fisheries.**

- **Agroforestry** denotes a sustainable land and crop management system that strives to increase yields on a continuing basis, by combining the production of woody forestry crops (including fruit and other tree crops) with arable or field crops and/or animals simultaneously or sequentially on the same unit of land, and applying management practices that are compatible with the cultural practices of the local population. (ICRAF 1982)

  - The productivity in agroforestry system is higher as compared to sole cropping systems, because higher yield of crop has been observed in forest influenced soil than in ordinary soil.

- Intercropping is the cultivation of two or more crops at the same time in the same field.
- India is the largest producer and exporter of Ginger (>50 countries & accounting for >50% of world production) and turmeric (75% of world output but export quality is 10-15% of production only) in the world.
- originally practiced as an insurance against crop failure under rainfall conditions
- Presently to achieve stability in production and higher productivity per unit area
- Judicious Utilization of resources(Land, Labour and Inputs) with increased total productivity
- Insurance against total crop failure under aberrant weather conditions or pest epidemics

Different aspects of Intercropping

- Detailed Planning
- Timely Planting and Aftercare of each crop
- Adequate fertilization at optimal rate and times
- Effective weed , pest and disease control
- Efficient Harvesting
- Post Harvest Processing, If Required
- Assured Marketing at optimum time and Price

Intercropping in fruit crops

- Fruit crops as intercrops

✓ Short-term and early bearing fruit crops as an intercrop, due consideration is essential in the selection of a particular fruit.

✓ This is essential because the roots of such trees may start competing with the roots of main fruit trees for nutrients and moisture.

✓ The filler trees, unless removed at appropriate time when primary fruit trees start giving economic crop, may create problems of low orchard efficiency.

✓ Wherever pineapple and strawberry can be grown, these may serve as an ideal intercrop.

- ✓ Wherever frost hazard is less, an intercrop of papaya can be taken profitably in a mango orchard.
- ✓ Likewise, in the northern plains of India, 'Sharbati' peach can be an excellent intercrop for mango orchard.
- ✓ Phalsa and guava could also be included in the early stages of growth of the trees, provided these are maintained properly by adequate pruning and removal at proper time.

Vegetable as intercrops in fruit orchards

Fruit crop	Intercrops
1. Guava	Cauliflower, French Bean, Pea, Lobia, Mung Bean and Cucurbits
2. Grapes	Pea, Cauliflower, French Bean, Chilies, Spinach, Marigold, Gladiolus and Jasmine
3. Papaya	Cauliflower, Onion, Tomato, Capsicum, and Peas.
4. Citrus	Cauliflower, Onion, Tomato, Bitter Guard, Bottle Guard, Peas and Okra.
5. Peach	Turmeric, Ginger, Soybean and Cowpea
6.Litchi and Mango	Turmeric, Ginger, Bitter Guard, Bottle Guard, Tomato, Raddish and Cauliflower,

Principles of intercropping

- Intercrops should occupy a secondary place in the orchard, primary consideration being given to the perennial fruit trees.
- The crops that may grow tall and have a tendency towards excessive growth should be discouraged.
- At least 120 cm radius must be left from the base of the growing fruit trees for taking intercrops.
- Such intercrops should be selected that do not exhaust the nutrients and moisture from the soil, so essential for the growth of fruit trees.
- Perennial or exhaustive crops should be discouraged as an intercrop in the orchard.
- This may have devitalizing effect on the growing trees. For example, sugarcane, pigeonpea, maize, jowar should invariably be excluded from an intercropping programme in the orchard.

Advantages of Intercropping

- Intercropping gives additional yield income/unit area than sole cropping.
- Inter-crops maintain the soil fertility as the nutrient uptake is made from both layers of soil.
- Reduction in soil runoff and controls weeds.
- Intercrops provide shade and support to the other crop.
- Inter cropping system utilizes resources efficiently and their productivity is increased.
- Intercropping with cash crops is highly profitable.

Disadvantages of Intercropping

- Yield decreases as the crops differ in their competitive abilities.
- Management of intercrop having different cultural practices seems to be difficult task.
- Improved implements cannot be used efficiently.
- Higher amount of fertilizer or irrigation water cannot be utilized properly as the component crops vary in their response of these resources.
- Harvesting is difficult.

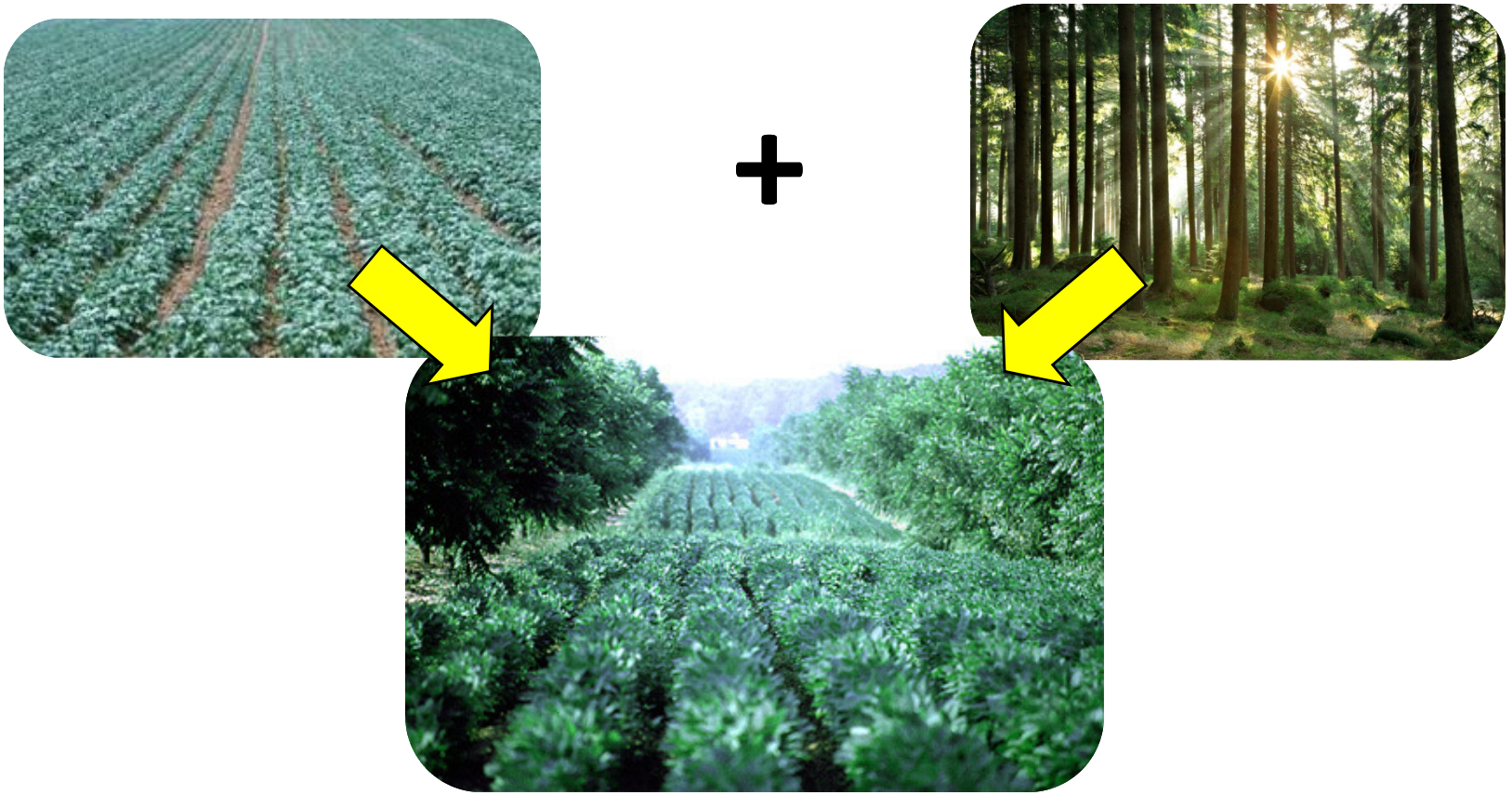
Table 1 . Intercropping tuber crops in litchi orchard

Treatment	Yield (t/ha)	Cost of cultivation	Net return (Rs/ha)	B:C Ratio
Sweet potato(30:20:30 NPK kg / ha)	11.75	9315	20046	2.15
Sweet potato (60:40:60 NPK kg/ ha)	15.50	10225	27527	2.70
Amorphophallus (40:30:40) NPK kg / ha)	25.50	47000	108001	2.29
Amorphophallus(80:60:80 NPK kg / ha)	31.50	49000	140000	2.85
Callocasia (40:30:40 NPK kg / ha)	17.65	11225	41749	3.72
Callocasia(80:60:80 NPK kg / ha)	19.95	12000	47833	3.99
Turmeric (40:30:40 NPK kg / ha)	13.35	11225	28750	2.55
Turmeric (80:60:80 NPK kg / ha)	14.85	12000	32583	2.70

Factors to be taken while choosing intercrops

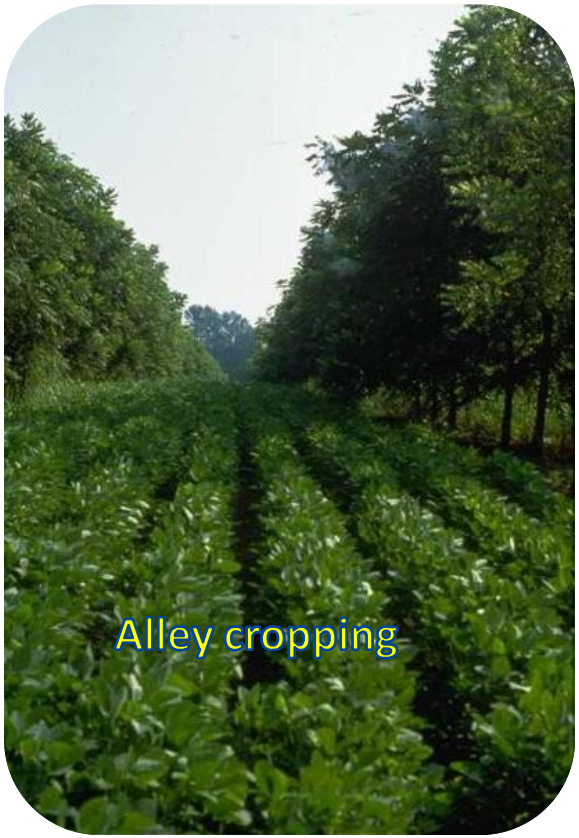
- Orchard which are nearer to cities or towns, better to grow vegetables as intercrops
- Intercrops should be selected that do not exhaust the nutrients and moisture from soil.
- For young orchards, vegetables which require abundant sun-light can be selected. For old orchards shade loving crops are preferred.
- Legumes are better choice for soil poor in nitrogen.
- Vegetables that have their roots within 25 cm depth of soil (tomato, onion, cauliflower, beans, radish).
- Pest and disease problems are enhanced by growing two or more crops together.

- ✓Take leguminous crops for cover cropping so that nitrogen fixation in orchard is facilitated.
- ✓Crops like sunhemp in light soils and Dhaincha in heavy soils may be grown to protect orchard soil from erosion.
- ✓Colocasia, ginger, and turmeric are heavy feeder and should be grown with supplemental doses.
- ✓Crops which are well adapted to climatic and soil conditions should be selected.
- ✓Exhaustive crops should be discouraged as an intercrop in the orchard. e.g. Sugarcane, pigeonpea, maize etc.



What is agroforestry?

…..the *intentional* combining of agriculture and working trees to create sustainable farming systems.



Why *Agroforestry?*

- ***Produces salable products***
- ***Provides value-added opportunities***
- ***Diversifies risk***
- ***Increases property values***
- ***Increases crop yields & livestock production***
- ***May be eligible for cost-share & land rental payments***

Effect of Agroforestry

Negative effect (or competition):

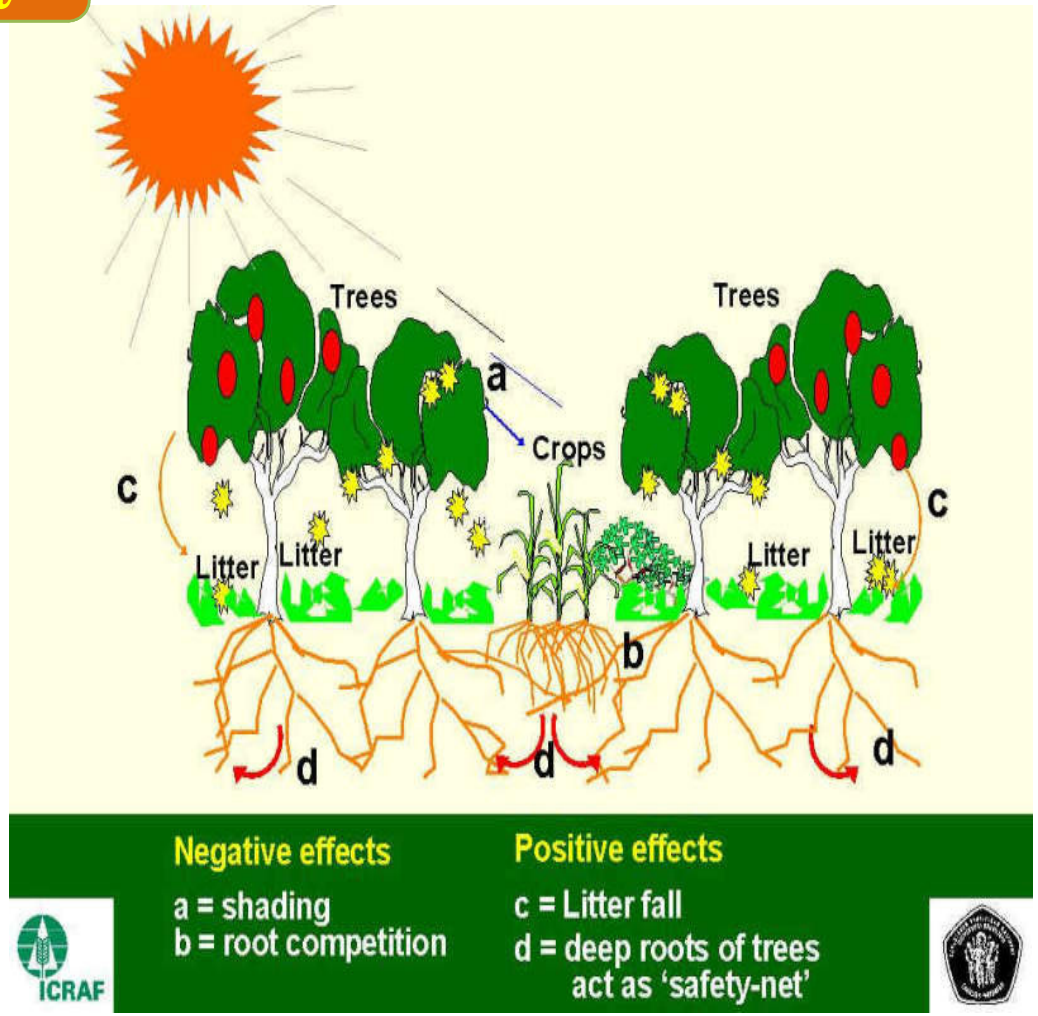
a = shading;

b= root competition for water and nutrient;

Positive effect (or complementary):

c = litter fall and pruning biomass of trees increase C, N, P and other nutrients;

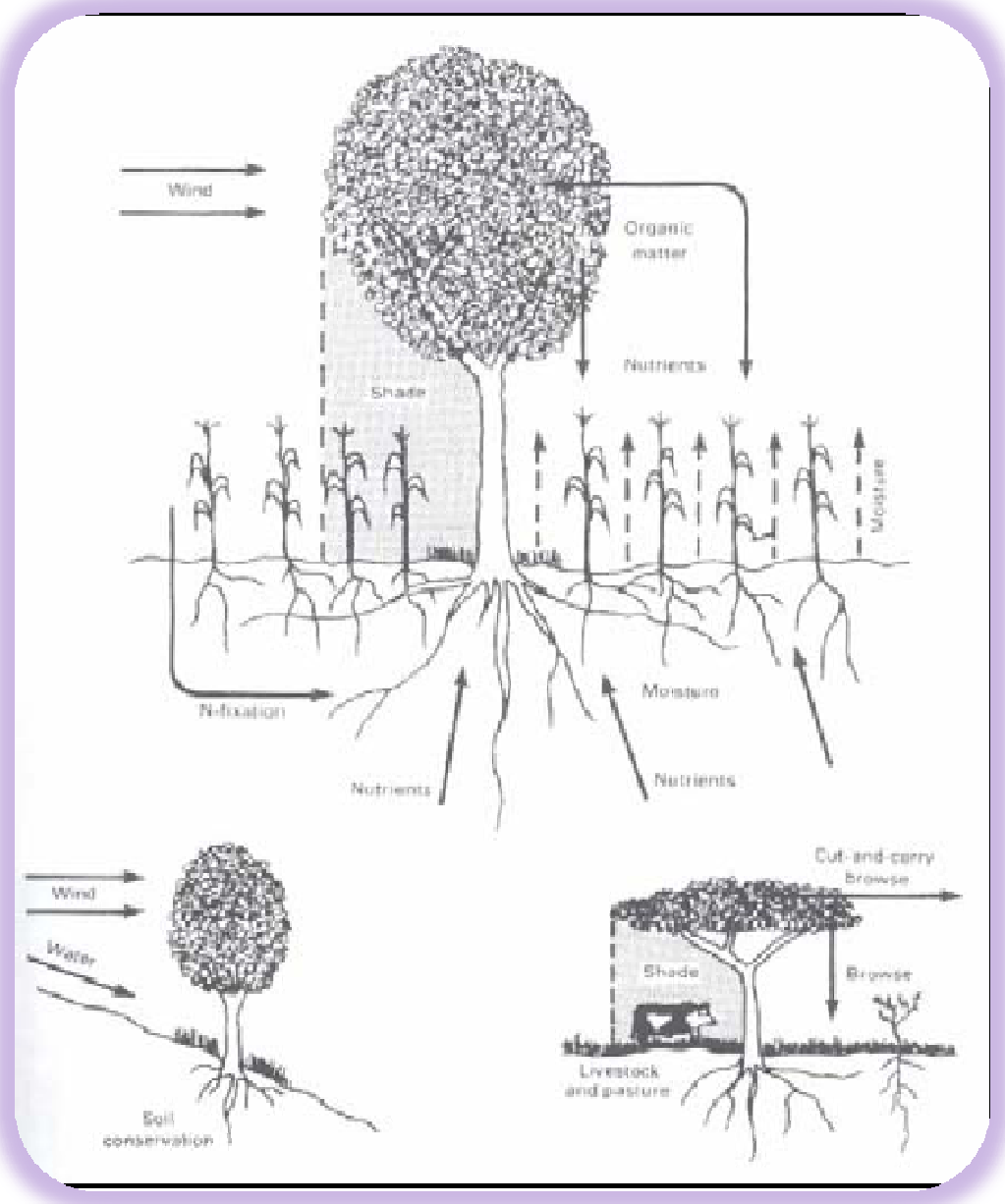
d = deep rooted trees play a role as 'safety-net' for leached nutrients in the deeper layer or as 'nutrient-pump' for fertile soil.



Agroforestry system has either positive effect of adding nitrogen and other nutrients and improve soil condition by mulching the leaves or negative effect of the trees competing with the crops for water and light.

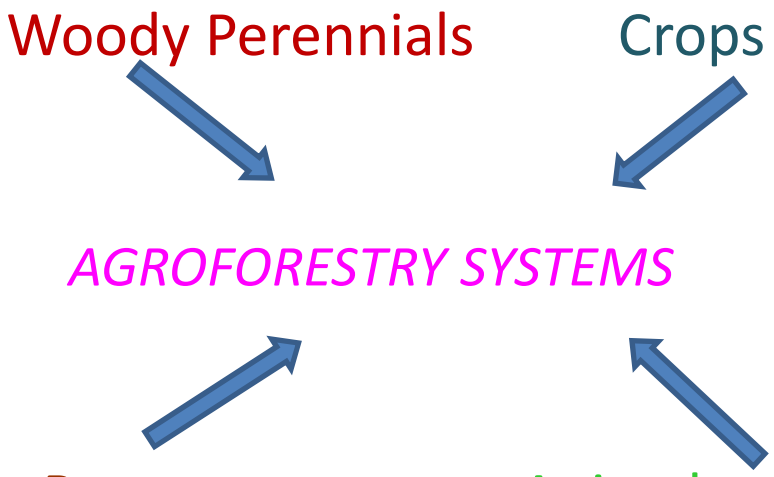
IMPROVEMENT OF SOIL FERTILITY IN AGROFORESTRY ?

- **Leaf litter decomposes and adds nutrients.**
- **Even the root systems release nutrients and improve soil structure when they decompose.**
- **Some trees capture nutrients lying deep in the soil, too deep for crops to reach, and bring them to the surface and later return them to the soil as litter, which the crops utilize when it decomposes.**
- **If leaves and branches are left on the ground to decompose and their nutrients are lost, the tree will have to be nourished with equivalent nutrients added as fertilizer or organic manure.**



Agroforestry – An old practice, but a new science:

- ✓ A multifunctional land use system.
- ✓ A Specialized way of farming crops and trees in various combinations on the landscape.
- ✓ Enhance livelihoods and contribute to resolving climate change effects.



Putting the right plant, in the right place, for the right purpose!

Agroforestry Practices

Agroforestry can be practiced on:

Benefits from agroforestry:

- ✓ Reduces pressure on forest
- ✓ Efficient recycling of nutrients through mining by deep- rooted trees
- ✓ Better protection of ecological systems
- ✓ Reduction of surface run-off, nutrient leaching and soil erosion
- ✓ Improvement of microclimate, such as lowering of soil surface temperature and reduction of evaporation of soil moisture through mulching and shading
- ✓ Increment of soil nutrients through addition and decomposition of litter-fall

Benefits from agroforestry (cont.):

- ✓ Improvement of soil structure through constant addition of organic matter from decomposed litter
- ✓ Increment in outputs of food, fuel wood, fodder, fertilizer and timber
- ✓ Reduction in incidence of total crop failure
- ✓ Increase in levels of farm incomes due to improved and sustained productivity
- ✓ Improvement in rural living standards from sustained employment and higher incomes
- ✓ Improvement in nutrition and health due to increased quality and diversity of food outputs

Agroforestry Means:

- ***Clean water and air***
- ***Safe and healthy food***
- ***Abundant wildlife***
- ***Beautiful places***
- ***Clean renewable energy***
- ***Sustainable family farms***





Area under Agroforestry in India

- A total of 25.32 million hechare(8.2% of the total geographical area of the country) (Dhyani et al.,2013)
- 53.32 Mha. Area (17.57% of the total geographical area) could be potentially under Agroforestry.
- Average sequestration potential in agroforestry in India is 25 t C per ha.

Trees on farms improve productivity in 2 ways

- Tree-crop combination can increase amount of water used
- increase productivity of water that is used by increasing biomass of trees or crops produced per unit of water.

Carbon stored in block and boundary plantations a mitigation potential of 48.5, 62.7, 61.7, 60.8, 37.6 tC/ha/yr respectively for Khair, Chir pine, mixed plantations, Mango/Kinoo farm forestry systems in Uttaranchal.

POTENTIAL OF AGRO-FORESTRY TOWARDS C SEQUESTRATION

- AF- an innovative practice of introducing trees in farming C sequestration through AF offers many advantages
- In humid tropics, AF systems are found to offer C sequester over 70 Mg/ha in the top 20 cm of the soil.
- According to IPCC (2007), the AF systems offer a technical mitigation potential of 1.1-2.2 PgC in terrestrial ecosystems over the next 50 years.
- Additionally, 630 Mha of unproductive croplands and grasslands could be converted to AF representing a C sequestration potential of 391,000 MgC/yr by 2010 and 586,000 MgC/yr by 2040 (Jose, 2009). The carbon in the aboveground and belowground biomass in an AF system is generally much higher than the equivalent land use without trees (i.e. crop land without any trees).
- MgC = Mega Grams- Mega is 10^6
- GtC = Gigatonnes of carbon (1 GtC = (109 tonnes C = 3.67 Gt CO_2) – Giga is 10^9
- TgC = teragrams of carbon (1 TgC = 1 MtC) – Tera is 10^{12}
- PgC = petagrams of carbon (1 PgC = 1 GtC) - Penta is 10^{15}

C Stocks in AF Systems in India

- C sequestration in AF systems occurs – *Belowground* (enrichment of soil C + root biomass) and *Aboveground* as C stored in standing biomass.
- sequestration potential of 68-228 MgC/ha, and 25tC/ha over 96 Mha of land
- AF could store nearly 83.6 tC/ha up to 30 cm soil depth, 26% more C compared to cultivation in Haryana plains.
- annual C sequestration potential of planted tree species on abandoned agricultural land (3.9 t/ha/yr)
- on degraded forest land (1.79 t/ha/yr)
- *with Dalbergia sissoo* 0.141 tC/ha/ yr intercropped with wheat and paddy.
- With agri-silvicultural system 31.37 tC/ha
- With monocropping of trees and food crops gave 40% and 84% less than agri-silviculture indicating AF systems have more potential to sequester carbon.
- *Dalbergia sissoo @* 11 years was able to accumulate 48-52 t/ha of biomass
- Poplar based agri-silvicultural system – Total biomass in system was 25.2 t/ha, 113.6% higher than sole wheat cultivation, where net carbon storage was 34.61 tC/ha compared to 18.74 tC/ha in sole wheat cultivation
- C dynamics - tree biomass was 23.61 to 34.49 tC/ha with black gram-mustard

Classification of Agroforestry systems

Categorization of systems based on their structure and functions			Grouping of systems (according to their spread and management)	
Structure (nature and arrangement of components, especially woody ones)		Function (role and/or output of components, especially woody ones)	Agro-ecological environmental adaptibility	Socio-economic and management level
Nature of components	Arrangement of components			
Agrisilviculture (crops and trees incl. shrubs/trees and trees)	*In space* (spatial)	*Productive function*	*Systems in/for*	*Based on level of technology input*
Silvopastoral (pasture/animals and trees)	Mixed dense (e.g., homegarden)	Food	Lowland humid tropics	Low input (marginal)
Agrosilvopastoral (crops, pasture/animals, and trees)	Mixed sparce (e.g. most systems of trees in pastures)	Fodder	Highland humid tropics (above 1,200 m a.s.l., Malaysia)	Medium input
Others (multipurpose tree lots, apiculture with trees, aquaculture with trees, etc.)	Strip (width of strip to be *more than one tree*)	Fuelwood	Lowland subhumid tropics (e.g. savanna zone of Africa, Cerrado of South America)	High input
	Boundary (trees on edges of plots/fields	Other woods	Highland subhumid tropics (tropical highlands) (e.g. in Kenya, Ethiopia)	*Based on cost/benefit relations*
	In time (temporal)	Other products		Commercial
	* Coincident	*Protective function*		Intermediate
	* Concomitant	Windbreak		Subsistence
	* Overlapping	Shelterbelt		
	* Sequential (separate)	Soil conservation		
	* Interpolated	Moisture conservation		
		Soil improvement		
		Shade (for crop, animal and man)		

Agroforestry systems

Agri - silviculture

Silvi - pastoral

Agri - horticulture

Agri – silvi - horticulture

Shelterbelt and windbreak

Alley cropping

Home gardens

Agri-silviculture system
(Acacia mangium - a fast growing NFT species + crops):

- *Acacia mangium,* ht. 25-30 m, dbh 40-45 cm, 5-6 cft timber, Rs 3000/tree in10 years
- Sesame, successfully grown up to 4 years of tree growth, yield recovery 80-85 %

- **In this system, tree species are grown and managed in the farmland along with agriculture crops .**
- **The aim is to increase overall yield of the land. This system also based on the principle of sustained yield.**
- **Woody plants and crops interact both ecologically and economically.**
- **This system can be great value, if trees, and crops are appropriately well managed according to their requirements.**
- **This can solve the problem of shortage food, fuelwood, timber and conserve soil moisture contents and also ameliorate the harsh climatic condition.**

AGRISILVICULTURAL SYSTEMS

Agri-silvi system (*Acacia mangium/Gmelina arborea* + arrowroot):

Arrowroot, successfully grown from 5 to 8 years of tree growth, yield recovery 85%

Agri-silvi system (*tree*+ turmeric/ginger/colocassia):

Turmeric/ginger, successfully grown with *Acacia mangium/ Eucalyptus* from 5 to 8 years of tree growth, yield recovery 85%

Acacia mangium + turmeric

Acacia mangium + ginger

Acacia mangium + Colocassia

Eucalyptus + turmeric

Agri-silvi system (*Acacia mangium* + Pineapple/*Aloe vera*):

Pineapple, successfully grown from 8 to 11 years, yield recovery 85%

Aloe vera, successfully grown from 8 to 11 years, yield recovery 88%

Agri-silvi system (*Acacia mangium* + Patchouli/Kalmegh):

Patchouli or Kalmegh, grown from 7 to 10 years, yield recover 80%

Silvipasture

Combines timber, livestock and forage production on the same acreage. Trees provide longer-term returns, while livestock generate an annual income.

SILVIPASTORAL SYSTEMS

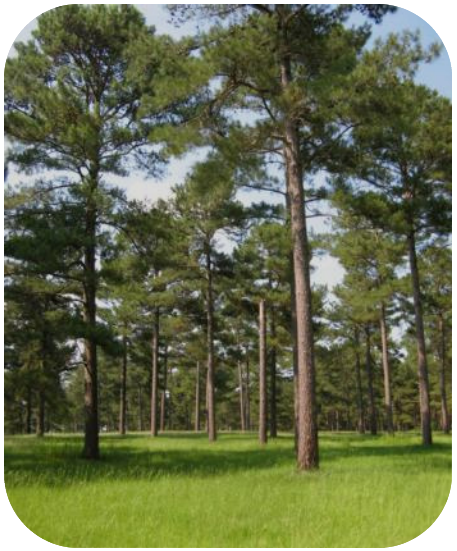
- In the silvipastoral system, improved pasture species are grown along with trees species. Here selection of tree species could be either timber alone or for dual purpose i.e. fuel cum fodder.
- Grass or grass-legume mixtures are grown along with woody perennials simultaneously on same unit of land.
- Combining of trees, grasses, and legumes also helps to conserve soil moisture and improve the fertility status of soil.

Silvi-pastoral system:

Hybrid Napier, successfully grown up to 4 years with 90% yield recovery & from 5 to 8 years with 80% yield recovery, then yield recovery reduced to 70% with *Eucalyptus*

Guinea grass, successfully grown up to 4 years with 90% yield recovery & from 5 to 8 years with 75% yield recovery, then yield recovery reduced to 65% with *Acacia mangium*

Silvipasture Benefits



- ***Improved plant vigor***
- ***Lower animal stress***
- ***Reduced wildfire risk***
- ***Improved wildlife habitat***
- ***Annual income (e.g. grazing, hay, straw etc.)***
- ***Long-term income (timber)***

Agri-Horticulturalsystem:

- If agricultural crops are grown along with fruit trees, the system is referred to as Agri horticulture system.
- This land management system aims at production of both agricultural and fruits crops.
- This practice could continue till 5 or 6 years or till canopy of fruit trees becomes fully closed.
- This system makes soil congenial for the rapid growth of fruit trees. However, if the fruit trees are planted at wider spacing, agriculture can continue simultaneously too.

Agri-horti-silvi system (*Acacia mangium* + Guava + Crops):

Amorphophallus, successfully grown up to 8 years of tree growth, yield 75-80%

Colocassia, successfully grown up to 8 years of tree growth, yield recovery 80-90%

AGROSILVOPASTORAL SYSTEMS

Horti- silvi-pastoral system (*Acacia mangium* + Guava + Stylo/guinea):

Stylo, successfully grown up to 6 years of tree growth, yield recovery 75-80 %

Guinea, successfully grown up to 6 years of tree growth, yield recovery 80%

Multilayered agroforestry systems:

Coconut based agroforestry systems:

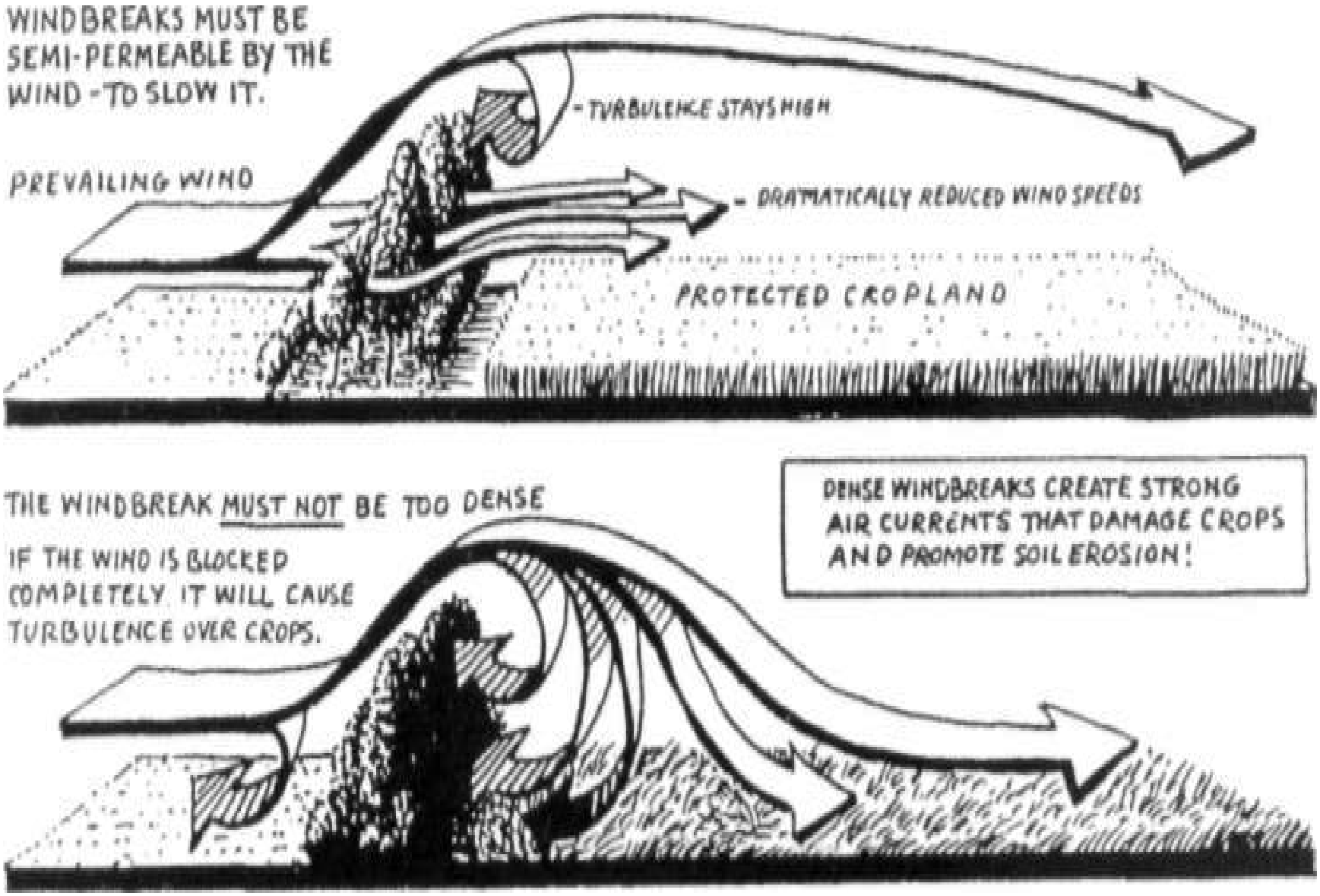
Windbreaks



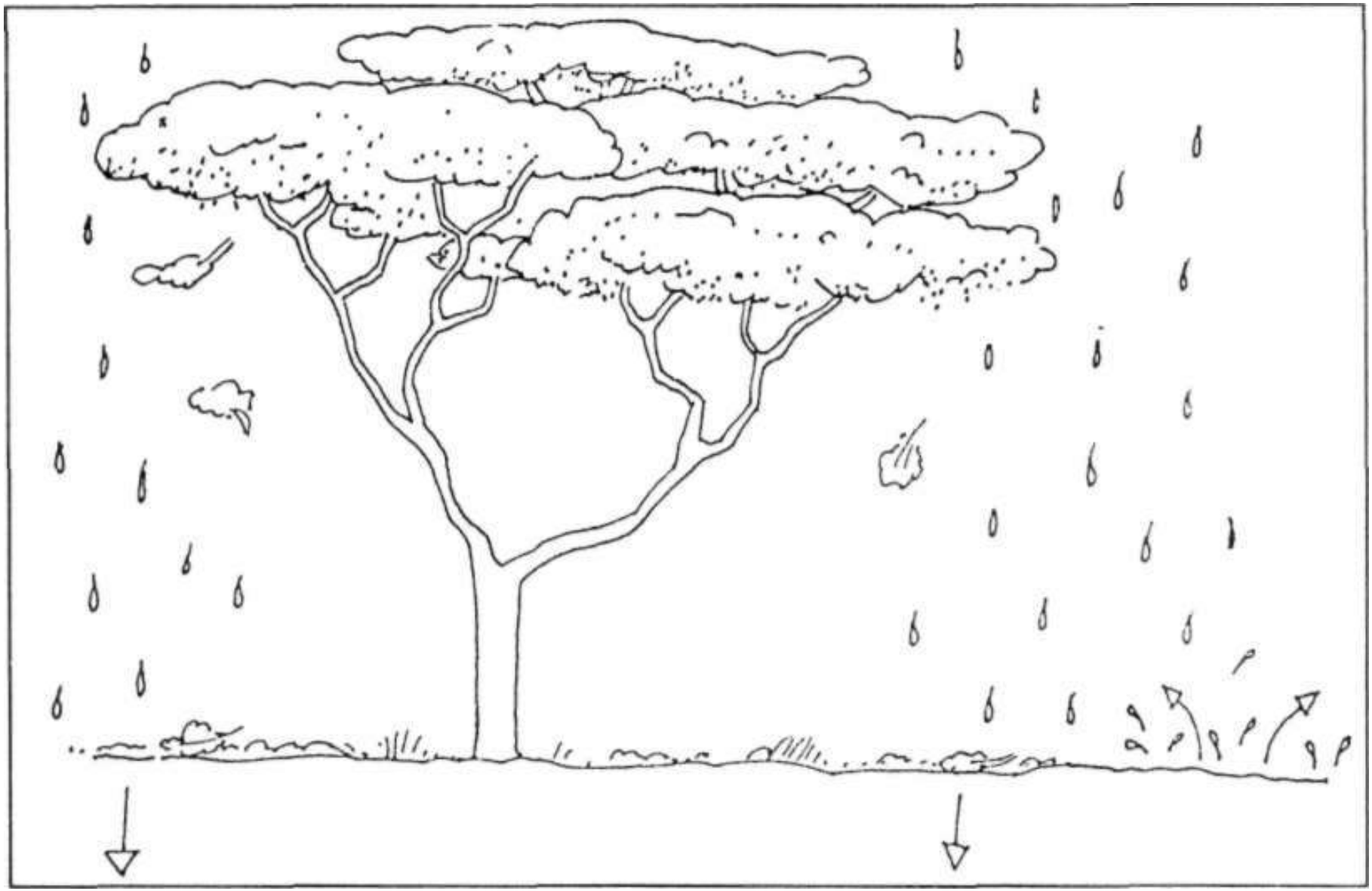



Plantings of single or multiple rows of trees or shrubs that redirect or modify the wind and are established for one or more environmental purposes.

Wind breaks


WINDBREAKS MUST BE SEMI-PERMEABLE BY THE WIND - TO SLOW IT.
- TURBULENCE STAYS HIGH
PREVAILING WIND
- DRAMATICALLY REDUCED WIND SPEEDS
PROTECTED CROPLAND
THE WINDBREAK MUST NOT BE TOO DENSE
IF THE WIND IS BLOCKED COMPLETELY IT WILL CAUSE TURBULENCE OVER CROPS.
DENSE WINDBREAKS CREATE STRONG AIR CURRENTS THAT DAMAGE CROPS AND PROMOTE SOIL EROSION!

Soil conservation : **Leaf mulch is important in preventing splash erosion and promoting Infiltration.**



Homestead agroforestry systems:

Paddy + Coconut + *Eucalyptus* + Banana + Colocassia + Seasonal vegetables

Paddy + Coconut + *Eucalyptus* + Mango + Seasonal vegetables + Fish

Home garden (Agri-horti-silviculture system)

is an operational farm unit in which a number of crops including tree crops are grown with livestock, poultry and/or fish production, mainly for the purpose of meeting the routine basic needs of the farmer. It is an old-age practice in coastal states particularly in Kerala, Tripura, Assam, North-eastern states and parts of West Bengal and Andaman and Nicobar Islands.

Home garden (Agri-horti-silviculture system)

Alley Cropping

Growing an annual or perennial crop simultaneously in the alley ways between rows of a long term tree crop. The agricultural crop generates annual income while the longer-term tree crop matures.

Alley Cropping Benefits

- ***Diversify farm enterprise***
- ***Reduce erosion***
- ***Improve water quality***
- ***Protect crops***
- ***Improve utilization of nutrients***
- ***Enhance wildlife habitat***
- ***Improve aesthetics***
- ***Store carbon***


ALLEY CROPPING OF MAIZE WITH SUBABUL

Live fences

Role of Agroforestry systems

Productive functions

The Productive functions are:

I) Food

II) Fodder

III) Fuel wood

IV) Otherwoods

V) Shelter

VI) NTFPs

Protective functions

The Protective functions are:

I. Wind break

II. Shelterbelt

III. Soil conservation

IV. Moisture conservation

V. Soil improvement

VI. Shade
(for crop , animal and men)

Bamboo based agro forestry systems with Ginger and Turmeric

- **Ginger (*Zingiher officinale L.*) is an important commercial crop grown for its aromatic rhizomes, which are used both as a spice and a medicine.**
- **India is the largest producer of ginger in the world accounting for about 50% of the total world production. While India , China, Taiwan, Sierra and Nigeria are the major exporter of dry ginger.**
- **In India a large portion of the ginger produced is consumed domestically as green ginger or dried ginger in a number of culinary preparations like curried and mixed vegetables, certain curried meats, table sauces, pickles, curry powders, etc.**
- **Globally ginger is widely used in the manufacture of ginger oil, ginger essence and gingerin and some alcoholic drink like ginger brandy, ginger wine, ginger beer and ginger ales. In India its use in these products is very limited.**
- **In processed ginger, very recently the manufacture of ginger paste has just began on a commercial scale. In the ayurvedic medical system, ginger is used as a carminative and stimulant. Ginger oil is used in medicated ointments.**

Turmeric production is an alternative adaptive crop in areas where other crops are damaged by wild animals

➢**Turmeric (*Curcuma longa L. Syn Curcuma domestica Val.) is a herbaceous perennial* plant belonging to the family, Zingiberaceae and order Scitaminae. It is an ancient, most valuable, sacred spice of India and it contains appreciable quantities of proteins (6.3%), lipids(5.1%), carbohydrates (69.4%) and fibre (2.6%).**

➢**Turmeric is rich in minerals like phosphorus, calcium, iron and vitamin A. It is cultivated for its underground rhizomes which is used as spice and condiment, dye stuff and in drug and cosmetic industry. It forms an important adjuvant in Indian culinary as it tends colour and aromatic flavour to various dishes.**

➢**It is mainly used as condiment, in the preparation of pickles and curries and as a colouring agent in textile, food and confectionary industries. Turmeric has lot of medicinal properties, it has long been used in India for the treatment of sprains and inflammatory conditions. The turmeric rhizome contains a variety of pigments among which 'curcumin' is the major pigment responsible for colour and it varies from 3.5 to 9.0 per cent in different varieties.**

Turmeric contain

- Curcumin – 3.5 – 9 %
- Oleoresin – 05 - 18.2%
- Dry recovery - 13.5 - 32.4%
- Essential oil – 0.05 – 10.2%
- **Yield capacity :**
- **17.4 - 37.47 t/ha fresh**

Ginger contain

- Essential oil : 1.72 - 2.36 %
- Dry recovery : 18 – 23. %
- Fibre content : 3 - 4 %
- Oleoresin: 4.48 - 6.73%
- **Yield capacity :**
- **22.4 – 26.6 t/ha (fresh) wt.**

Review of research work

Table 2 : Actual and projected exports of Indian turmeric to major importing countries

(in tonnes)

Year	USA		UK		Iran		Japan		UAE		Others	
	Actual	Estimated	Actual	Estimated	Actual	Estimated	Actual	Estimated	Actual	Estimated	Actual	Estimated
1999-00	2427	2783	1676	2074	2077	2086	1878	2355	8162	6455	21555	21543
	(6.43)	(7.46)	(4.44)	(5.56)	(5.50)	(5.59)	(4.97)	(6.31)	(21.61)	(17.31)	(57.06)	(57.76)
2000-01	2584	2188	1837	2081	2971	2515	3027	2560	6044	6691	28165	21741
	(5.79)	(5.79)	(4.12)	(5.51)	(6.66)	(6.66)	(6.78)	(6.78)	(13.54)	(17.71)	(63.11)	(57.55)
2001-02	2739	3236	1842	2177	2724	2658	2559	2636	5272	6226	22641	27694
	(7.25)	(7.25)	(4.88)	(4.88)	(7.21)	(5.96)	(6.78)	(5.91)	(13.95)	(13.95)	(59.93)	(62.06)
2002-03	3914	2717	2006	1959	949	2453	2614	2391	4724	5602	18196	22657
	(12.08)	(7.19	(6.19)	(5.19)	(2.93)	(6.49)	(8.07)	(6.33)	(14.58)	(14.83)	(56.16)	(59.97)
2003-04	3880	2662	2060	1918	488	1689	2694	2355	7239	5689	20683	18089
	(10.47)	(8.21)	(5.56)	(5.92)	(1.32)	(5.21)	(7.27)	(7.27)	(19.54)	(17.56)	(55.83)	(55.83)
2004-05	2508	2835	2576	2216	800	1851	2686	2693	5215	7044	29312	20406
	(5.82)	(7.65)	(5.98)	(5.98)	(1.86)	(5.00)	(6.23)	(7.27)	(12.10)	(19.02)	(68.02)	(55.09)
2005-06	2635	2955	2772	2399	1447	1879	2608	2422	7361	5970	29582	27472
	(5.68)	(6.86)	(5.97)	(5.57)	(3.12)	(4.36)	(5.62)	(5.62)	(15.86)	(13.85)	(63.75)	(63.74)
2006-07	2461	2943	2896	2660	6095	2503	2632	2787	7824	7127	29593	28385
	(4.78)	(6.34)	(5.62)	(5.73)	(11.83)	(5.39)	(5.11)	(6.01)	(15.19)	(15.36)	(57.46)	(61.17)
2007-08	2649	2973	2461	2730	3709	4552	2797	3187	5151	7317	32485	30741
	(5.38)	(5.77)	(5.00)	(5.30)	(7.53)	(8.84)	(5.68)	(6.19)	(10.46)	(14.21)	(65.96)	(59.69)
2008-09		3110		2460		3110		2780		6122		31726
		(6.31)		(4.99)		(6.31)		(5.64)		(12.42)		(64.34)
2009-10		3103		2548		2931		2944		6759		31024
		(6.29)		(5.17)		(5.94)		(5.97)		(13.71)		(62.92)
2010-11		3240		2609		2970		2988		7088		30414
		(6.57)		(5.29)		(6.02)		(6.06)		(14.37)		(61.68)
2015-16		3373		2690		3242		3131		7579		29294
		(6.84)		(5.46)		(6.57)		(6.35)		(15.37)		(59.41)
2020-21		3391		2695		3278		3146		7624		29175
		(6.88)		(5.47)		(6.65)		(6.38)		(15.46)		(59.17)

Note: Figures within the parentheses indicate percentage to total.

Dept. of Ag.Econo TNAU, Coimbatore

Angles *et al.*,(2011)

Ginger

Turmeric

Table 03: Economics of turmeric grown under different tree species.

Treatment	Yield (g/pl.)	Yield (kg/ha)	Total Gross realization (Rs.)	Net realization	CBR
T_1C_1	62.16	10349.64	67272.66	28229.80	1.73
T_1C_2	54.67	9102.55	59166.61	20123.75	1.52
T_2C_1	74.00	12321.00	80086.50	41043.64	2.05
T_2C_2	63.70	10606.05	68939.33	29896.47	1.77
T_3C_1	84.40	14051.72	91336.49	52293.63	2.34
T_3C_2	65.48	10,902.42	70865.73	31822.87	1.82
T_0C_1	53.43	8896.09	57824.62	18781.76	1.48
T_0C_2	45.98	7655.67	49761.86	10719.00	1.27

NAU, Navsari **Prajapati (2006)**

T_1 – *Terminalia arjuna*
T_2 – *Casuarina equisetifolia*
T_3 – *Mitragyna parvifolia*
T_0 – Control (Open field)
C_1 – Kesar (Turmeric)
C_2 – Sugundham (Turmeric)

Table 04 : Effect of age of Poplar on growth and fresh rhizome yield of turmeric

Age of Poplar (Years)	Plant height (cm)	Fingers/ plant	Finger weight (g)	GBH of Poplar (cm)	Turmeric yield (q/ha)
1	155.0	12.4	30.1	24.4	162.4
2	145.0	8.9	26.4	48.9	101.7
3	82.8	9.9	15.8	53	53.1
Pure/ Sole	82.7	12.0	11.3	-	182.9
C.D. at 5 %	16.1	3.0	7.2	3.2	20.7

PAU, Ludhiana **Gill *et al.*, (2004)**

Table 05: Crop yield (t/ha) of intercrops under different tree species

Species	2003		2004		2005	
	Ginger	Turmeric	Ginger	Turmeric	Ginger	Turmeric
A. nepalensis	5.30	5.14	5.51	5.30	6.22	5.64
M. azadirachta	5.29	5.14	5.50	5.25	6.20	5.60
G. arborea	5.27	5.13	5.49	5.23	6.18	5.60
control	5.22	5.10	5.19	5.07	5.11	5.01
CD at 5%	NS	NS	NS	NS	1.09	0.61

Dept. of Forestry, Mizoram univ.,Aizawl **Vanlalhluna and Sahoo(2009)**

Table 06 : Effect of pruning management of *Ceiba pentandra* and FYM level on the economics of Ginger (Based on market rate of 2003)

Treatments	Yield of ginger (tons/ha)	Gross return (Rs./ha)	Total cost (Rs./ha)	Net realization (Rs/ha)
Tree crown management				
P_1 (25% pruned)	12.41	186150.00	134029.71	52120.29
P_2 (Un-pruned)	14.39	215887.50	134029.71	81389.02
P_3 (Treeless control)	9.89	14425.00	134029.71	14395.29
FYM Levels				
F_1 (0 tons/ha FYM)	10.31	154750.00	131217.18	23532.82
F_2 (10 tons/ha FYM)	11.55	173300.00	133092.18	40207.82
F_3 (20 tons/ha FYM)	13.01	195200.00	134967.18	59607.78
F_4 (30 tons/ha FYM)	14.04	210700.00	136842.29	73857.71

Dept. of forestry, IGAU, Raipur (CG) **Prapajati *et al.* , (2007)**

Table 07 : Yield of Aonla and intercrops under agri-horticultural systems

Treatment	Aonla fruit (t/ha)				Intercrop (q/ha)			
	2007	2008	2009	Average	2007	2008	2009	Average
Aonla (sole)	5.75 (20.8)*	8.75 (31.6)	7.04 (25.4)	7.18 (25.9)	–	–	–	–
Aonla + turmeric	11.63 (42.0)	15.71 (56.7)	12.57 (45.4)	13.30 (48.0)	260.4 [7.5]**	248.2 [9.6]	227.1 [12.0]	245.2 [9.7]
Aonla + ginger	9.16 (33.1)	12.96 (46.8)	9.70 (35.0)	10.61 (38.3)	110.5 [12.2]	100.9 [16.5]	92.3 [19.3]	101.2 [16.0]
Aonla + arbi	10.24 (37.0)	14.02 (50.6)	10.86 (39.2)	11.71 (42.3)	107.6 [15.7]	102.4 [18.2]	88.7 [25.3]	99.6 [19.7]
Mean	9.20 (33.2)	12.86 (46.4)	10.04 (36.3)					
CD ($P = 0.05$)				1.30				

*Figures in small brackets indicate the yield of aonla fruit in 'kg/tree'.

**Figures in square bracket indicate the reduction in the yield of intercrop in percentage compared to sole-cropping.

Dept. of forestry, RAU, Pusa, Samistipur

Das *et al.* , (2011)

Table 08 : Economic returns (Rs./ha) of different crops grown sole and in association with Aonla

Treatment	Return (Rs/ha)		Gross income (a + b)	Total expenditure (c)	Net return (a + b–c)	Benefit : cost ratio
	Aonla (a)	Crop (b)				
Aonla (sole)	86,160	–	86,160	21,528	64,632	3.00
Aonla + turmeric	169,600	367,800	537,400	73,735	463,665 (399,033)*	6.29
Aonla + ginger	127,320	303,600	430,920	96,927	333,993 (269,361)*	3.45
Aonla + arbi	140,520	79,680	220,200	52,479	167,721 (103,089)*	3.20
Without aonla						
Turmeirc	–	407,100	407,100	59,383	347,717	5.86
Ginger	–	361,500	361,500	82,575	278,925	3.38
Arbi	–	99,200	99,200	38,127	61,073	1.60

*Figures in parentheses indicate additional income over sole orcharding.

Dept. of forestry, RAU, Pusa, Samistipur **Das *et al.* , (2011)**

Table 09: Crop sequence along with Poplars in few states

Poplar Plantation type	Uttarakhand	Haryana	Punjab
Boundary	Paddy + Wheat	Paddy + Wheat	Paddy + Wheat
Boundary	Sugarcane	-	Fishery
Boundary	Paddy (Kharief)+ Wheat (Summer) +Pea (Rabi)	-	-
Block	Sugarcane (I & II year) + Wheat (III Year onwards)	Sugarcane (I & II year) + Wheat (III Year onwards)	Sugarcane (I & II year) + Wheat (III Year onwards)
Block	Forage Berseem	Forage Berseem	Potato
Block	**Ginger/Turmeric**	Mango/Litchi **+ Ginger/Turmeric**	**Ginger/Turmeric**
Block	Wheat/Potato	Wheat/Potato	Fodder crops, Wheat/Potato
Block	-	Vegetables (I & II Year) +Wheat (III Year onwards)	Flower Plants (Rose/Merigold)

Dept. of Forestry, NRCAF, Jhansi **Chaturvedi *et al.* (2009)**

Table 10 : Intercropping with Khasi Mandarin Orchards

Crop Combination	Crop Yield (q/ha)	Gross return (Rs/ha)	Net Return (Rs/ha)
Mandarin + Groundnut	15.0	8,180	3530
Mandarin + Soybean	13.4	6,930	2460
Mandarin + Rice	18.9	3,237	1760
Mandarin + Ginger	92.0	27,390	7810
Mandarin + Turmeric	108.2	18,960	4510

ICFRE, Dehradun **Tewari, D.N.(1995)**

Table 11: Income from various crops grown with poplars

Poplars with	Yield (Kg/ha)	Duration (Months)	Gross income (Rs/ha)	Net income (Rs/ha)
Tomato Seed	-	4-5	7500	3100
Onion	15000	5	7500	1800
Ginger	1100	8-9	11000	**3400**
Turmeric	4000	8-9	14000	**3900**
Carrot seed	200	4	3000	1150
Turnip seed	300	4	3000	1250
Mistard	800	3-4	2400	14
Soybean	2500	4	4000	1700
Peas	4000		5000	2200
Berseem (green)	50000	3	5000	2400
Pulses (black/green gram)	1000	5-6	2200	1000

Tejwani, K.G. (1994)

Table 12: Economics of Ginger production under sissoo based multistrata cropping system (average of two years)

Treatment	Return (Tk./ha)				Gross Return (Tk./ha)	Total cost of Production (Tk./ha)	Net Return (Tk./ha)	BCR
	Garlic	Guava	Lemon	Sissoo				
S_1+G_1+Garlic (T_1)	30900	157081	---------	153904	341885	82412	259473	4.15
S_1+L_1+ Garlic (T_2)	44625	---------	115002	153904	313531	78626	234905	3.99
S_2+G_2+ Garlic (T_3)	40230	118706	--------	140500	299436	72782	226654	4.11
S_2+L_2+ Garlic (T_4)	66150	-------	83201	140500	289851	70353	219498	4.12
S_3+G_3+ Garlic (T_5)	50317	74193	---------	113592	238101.9	61122	176979	3.90
S_3+L_3+ Garlic (T_6)	78635	--------	49499	113592	241726.1	59781	181945	4.04
Open (T_7)	182400	---------	--------	---------	177330	56471	120860	3.14

Note: Garlic 30 Tk./kg, Guava 6 Tk./kg; Lemon 1 Tk./piece, Sissoo (T1 & T2) 179 Tk./tree/year, Sissoo (T3 &T4) 250 Tk./tree/year, Sissoo (T5 & T6) 358 Tk./tree/year

T^1 = sissoo (spacing 4m x 4m) + guava (spacing 2m x 2m) + ginger;
T^2 = sissoo (spacing 4m x 4m) + lemon (spacing 2m x 2m) + ginger;
T^3 = sissoo (spacing 5m x 5m) + guava (spacing 2.5m x 2.5m) + ginger;
T^4 = sissoo (spacing 5m x 5m) + lemon (spacing 2.5m x 2.5m) + ginger;
T^5 = sissoo (spacing 6m x 6m) + guava (3m x 3m)+ ginger;
T^6 = sissoo (spacing 6m x 6m) + lemon (spacing 3m x 3m) + ginger
T^7 = Control (sole cropping of ginger).

Dept. of Agroforestry, HMDS&T Univ.Bangladesh **Bari *et al.* (2010)**

Table 13 : Growth and Yield contributing characters of turmeric grown under different agroforestry systems.

Treatment	Plant Ht. (cm)	Leaf length (cm)	Leaf breadth (cm)	Weight of fresh rhizome/clump (g)	Yield (t/ha)
Coconut + Guava + Turmeric,	105.65	87.55	14.62	570.34	38.78
Coconut + Lemon + Turmeric,	110.10	90.49	15.49	429.89	26.63
Turmeric (open condition).	95.94	67.29	11.93	430.80	30.49
LSD(.01)	5.89	4.46	2.13	9.97	2.67

Bangladesh Ag.Univ, Mymensingh

Ahmed *et al.* (2007)

Various Agro forestry plantations :

Table 14 : Growth and Yield contributing characters of ginger grown under different agroforestry systems.

Treatment	Plant Ht. (cm)	Leaf length (cm)	Leaf breadth (cm)	Weight of fresh rhizome/clump (g)	Yield (t/ha)
Coconut + Guava + ginger,	97.71	18.33	2.37	380.40	32.43
Coconut + Lemon + ginger,	76.62	24.67	2.67	265.20	17.81
Ginger (open condition).	66.26	16.54	2.10	281.80	23.98
LSD(.01)	4.54	3.43	0.29	12.11	7.76

Bangladesh Ag.Univ, Mymensingh

Ahmed *et al.* (2007)

Table 15 : Soil fertility status after harvest of different field crops with and without association of neem (*Azadirachta indica*)

Sr. No.	Treatments	Organic carbon (%)	Available nutrients (kg ha^{-1})		
			N	P	K
1	Neem sole	0.26	174.7	36.40	216.3
2	Neem + clusterbean	0.29	189.0	37.12	208.7
3	Neem + cowpea	0.31	197.3	38.15	205.0
4	Neem + greengram	0.30	191.3	39.34	192.3
5	Neem + til	0.28	180.7	36.56	200.0
6	Clusterbean sole	0.20	151.7	33.45	181.7
7	Cowpea sole	0.18	150.7	32.30	185.3
8	Greengram sole	0.21	159.0	31.94	185.0
9	Til sole	0.19	154.7	33.16	175.7
	CD at 5 %	0.08	20.29	NS	NS

Sardarkrushinagar **Anonymous** (2005)

Table 16 : Soil fertility status after harvest of different field crops with and without association of Shisham (*Dalbergia sissoo*)

Sr. no	Treatments	Organic carbon (%)	Available nutrients (kg ha^{-1})		
			N	P	K
1	Shisham sole	0.31	181.0	34.17	196.0
2	Shisham + clusterbean	0.30	182.7	33.53	200.0
3	Shisham + cowpea	0.29	176.7	32.36	197.7
4	Shisham + greengram	0.33	190.3	35.80	203.7
5	Shisham + til	0.29	183.7	34.50	186.7
6	Clusterbean sole	0.19	151.7	28.72	170.0
7	Cowpea sole	0.21	156.7	29.94	173.7
8	Greengram sole	0.20	162.0	27.66	168.3
9	Til sole	0.21	153.7	28.24	164.3
	CD at 5 %	0.07	21.49	5.24	NS

Sardarkrushinagar

Anonymous (2005)

Table 17 :Effect of agroforestry systems on fertility and moisture status of soil

Treatment	Organic carbon (%)	Available nutrients (kg/ha)			Moisture status (%)	
		N	P	K	0-15cm	15-30cm
Sole maize crop	0.48	252.5	20.2	280.5	11.1	13.7
Subabul alone	0.46	180.2	12.5	250.0	8.3	10.0
Shisham alone	0.40	192.5	12.5	260.7	7.1	7.2
Shisham + Maize	0.61	265.3	23.5	260.7	10.6	10.8
Subabul + Maize	0.72	283.5	25.5	320.5	11.6	12.2

NRCAF, Jhansi

Anonymous (2000)

Table 18 : Comparison of tree-crop interaction in teak based agroforestry under red soil

Agroforestry system	Benefits from AFS (%)	Changes in soil properties (%)				
		Available nutrients				
		N	P_2O_5	K_2O	pH	EC
S	(10225)	(184)	(20)	(168.7)	(6.12)	(0.4)
S+T	+147.6	+7.6	+19.4	+14.9	-7.3	-5.0
S+T+G	+110.0	+7.9	+14.4	+24.5	-1.4	-2.5
S+T+Sb	+39.2	+13.0	+17.9	+20.7	-1.8	-7.5

S - Sorghum, T-Teak, G-Grass, Sb-Subabul seedling

Department of Forestry, Dharwad

Mutanal and Nadagoudar (2004)

Table 19 : Comparison of tree-crop interaction in teak based agroforestry under red soil

Agroforestry system	Benefits from AFS (%)	Changes in soil properties (%)				
		Available nutrients				
		N	P_2O_5	K_2O	pH	EC
Gn	(8188)	(192.2)	(21.2)	(174)	(6.13)	(0.38)
Gn+T	+224.6	+4.4	+8.96	+15.5	-2.6	-2.6
Gn+T+G	+92.1	+4.4	+13.2	+17.7	-3.5	-2.6
Gn+T+Sb	+33.8	+9.4	+13.6	+18.1	-2.1	-5.2

T-Teak, G-Grass, Sb-Subabul seedling , Gn-Groundnut

Department of Forestry, Dharwad

Mutanal and Nadagoudar (2004)

Table 20 : Effect of agroforestry systems on soil properties

Soil properties	Agroforestry systems					
	Agrisilviculture	Agrihorti culture (khasi mandarin + crops)	Agrihorti culture (Assam lemon + crops)	Silvihorti pastoral (Alder + pine apple + fodder grass)	Multistoried AFS (Alder + tea+ black pepper + crops)	Natural forest
pH	4.65	4.62	4.80	4.25	4.61	4.62
Organic C (%)	1.62	1.55	2.02	2.19	1.91	1.92
Exchangeable Ca [cmol kg^{-1}]	0.40	0.31	0.74	0.86	0.65	0.26
Exchangeable Mg [cmol kg^{-1}]	0.48	0.51	0.33	0.75	0.71	0.16
Exchangeable K [cmol kg^{-1}]	0.232	0.244	0.238	0.249	0.201	0.169
Exchangeable Na [cmol kg^{-1}]	0.201	0.195	0.194	0.220	0.197	0.196
Exchangeable Al [cmol kg^{-1}]	2.65	2.70	2.20	3.15	2.05	2.20

Division of Soil Science, ICAR Research Complex, Meghalaya Majumdar *et al.* (2004)

Table 21 : Effect of different farming systems on soil properties

Farming system	pH	Organic C (g kg-1)	Exchange Al [cmol kg-1]	ECEC	Base saturation (%)
livestock	4.65	27.0	1.25	4.10	69.20
Forestry	4.41	28.7	1.53	3.0	48.25
Agroforestry	4.52	26.6	1.56	3.8	58.70
Agriculture	5.03	26.1	0.46	7.1	93.10
Agrihortisilvipastoral	4.92	29.7	0.90	5.2	81.20
Horticulture	4.91	29.7	0.90	4.9	81.20
Natural Fellow	4.99	29.4	0.88	4.1	78.50
Abandoned jhum land	4.76	34.2	1.30	3.9	66.4
S.D. ±	0.07	0.90	0.40	1.43	17.0

Division of Soil Science, Meghalaya

Majumdar *et al*. (2004)

Table 22 : Physico-chemical and fertility parameters of the soil under different land use systems

System	pH	EC (dSm^{-1})	OC (gkg^{-1})	Avail. N	Avail. P	Avail. K ($kgha^{-1}$)	Ca $cmolkg^{-1}$	Mg cmol k^{-1}
Silviagriculture	7.0	0.18	7.6	184.6	14.0	191.6	4.67	3.09
Agrihorticulture	6.9	0.17	7.7	194.7	12.1	147.0	3.15	1.84
Silvipasture	7.0	0.13	7.8	193.9	10.9	137.2	3.90	3.07
Silviculture	6.8	0.16	9.4	219.9	13.3	163.8	4.05	2.67
Pasture	6.4	0.08	6.9	164.0	9.6	139.6	2.52	1.70
Agriculture	5.9	0.05	6.3	155.0	7.6	54.8	2.17	1.06
Uncultivated Fallow	5.8	0.04	4.5	110.3	5.7	71.6	2.15	1.93
LSD (0.05)	0.24	0.02	1.2	25.0	2.2	12.5	0.25	0.50

Central Research Institute for Dryland Agriculture, Hyderabad Vittal *et al* . (2006)

Table 23 : Effect of different land-use systems on chemical properties of acid soil

System	pH	Organic carbon (%)	Electrical conductivity (dS m^{-1})	Cation exchange capacity (c mol kg^{-1})	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})
Forest	5.22	3.01	0.25	15.81	699	17.23	301.61
Grassland	5.69	2.16	0.24	15.20	426	15.47	285.21
Horticulture	5.46	1.68	0.25	14.90	401	13.24	271.5
Agriculture	5.50	0.90	0.23	14.30	301	12.31	265
Wasteland	5.60	0.85	0.22	13.80	286	11.48	264
LSD0.05	0.12	0.045	------	0.25	16.25	0.21	13.25

Central Soil and Water Conservation Research and Training Institute, Chandigarh Pal *et al.* (2013)

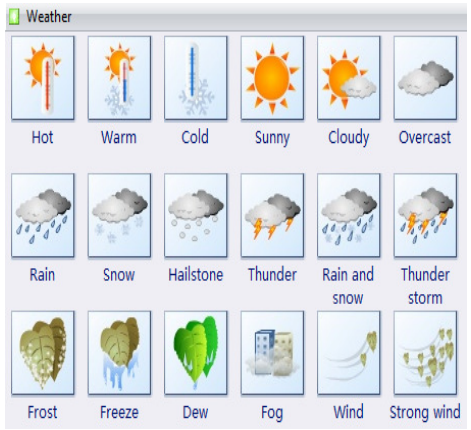
Table 24 : Soil properties of low land paddy under agrisilviculture systems in acid soil

Treatment	pH	EC (dS/m)	OC (%)	N (Kg/ha)	P_2O_5 (kg/ha)	K_2O_5 (kg/ha)
Salix tetrosperma	5.93	0.22	1.52	268.33	18.16	122.15
Bixa oreliana	5.85	0.16	1.35	258.30	14.64	105.52
Bombax ceiba	5.78	0.21	1.71	315.00	15.45	136.42
Pongamia pinnata	5.62	0.20	1.65	288.00	15.00	178.67
Lagerstroemia parviflora	5.65	0.19	1.72	322.33	21.48	218.67
Terminalia arjuna	5.99	0.34	2.15	375.33	24.24	238.7
Gmelina arborea	5.75	0.21	1.91	344.67	20.26	131.87
LSD0.05	--------	----	L=0.108	L=22.22	L=1.09	L=11.50

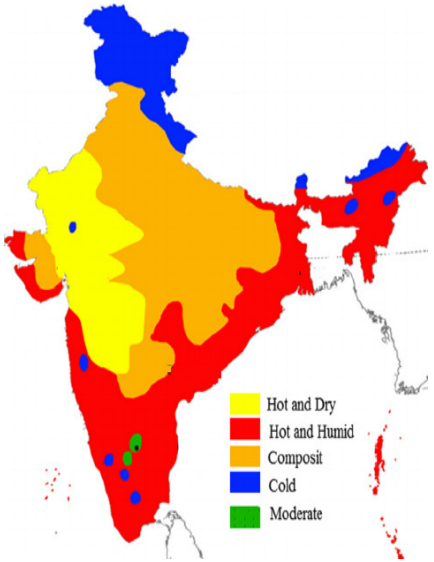
Central Soil and Water Conservation Research and Training Institute, Chandigarh, Panwar *et al.* (2013)

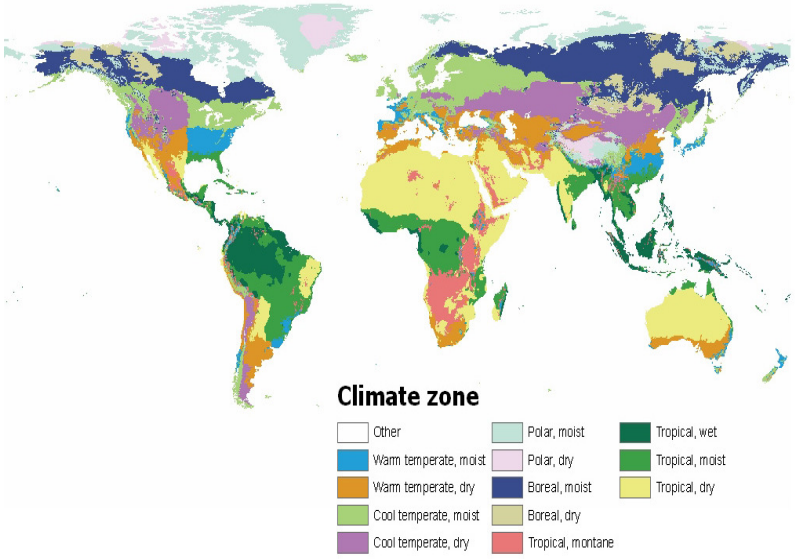
Weather and climate

Weather- "the state of the atmosphere with respect to heat or cold, wetness or dryness, calm or storm, clearness or cloudiness".



Climate – "the average course or condition of the weather at a place usually over a period of years as exhibited by temperature, wind velocity, and precipitation"

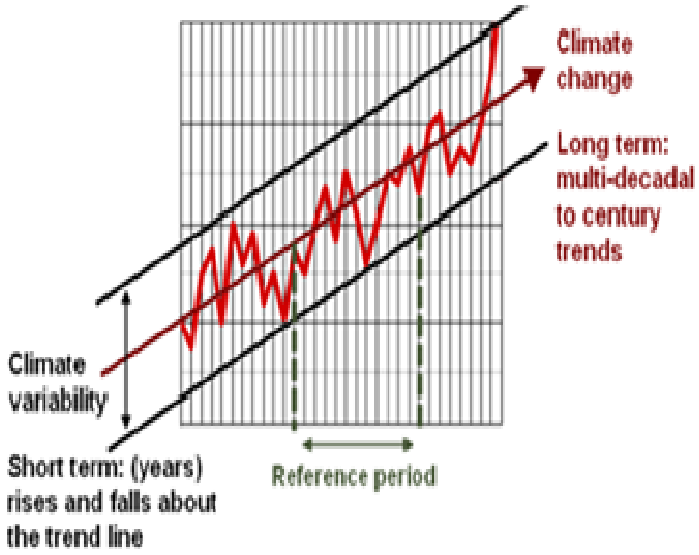




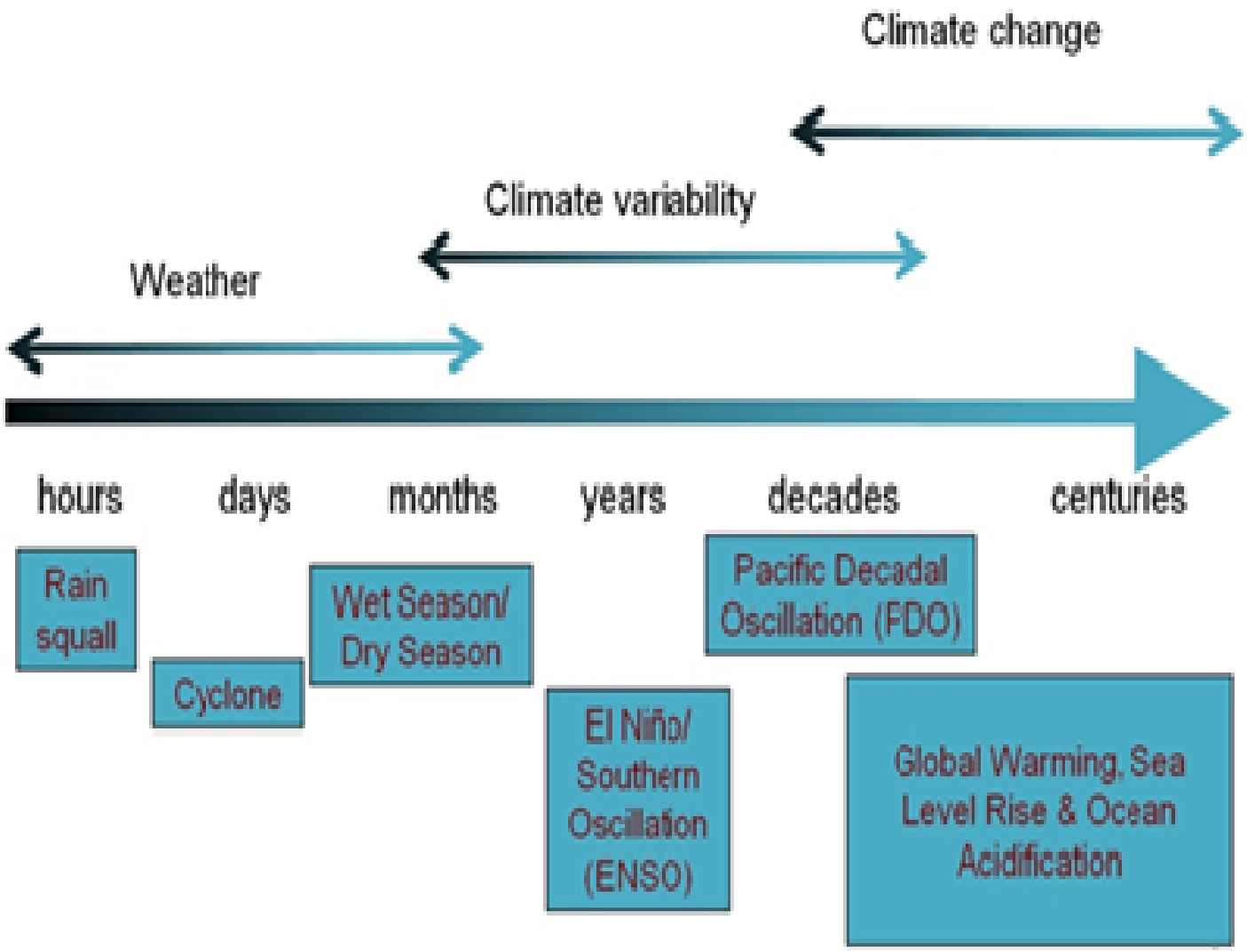
Climate Variability and Climate Change

Climate variability - variations in the mean state and other statistics of the climate on all temporal and spatial scales, beyond individual weather events.

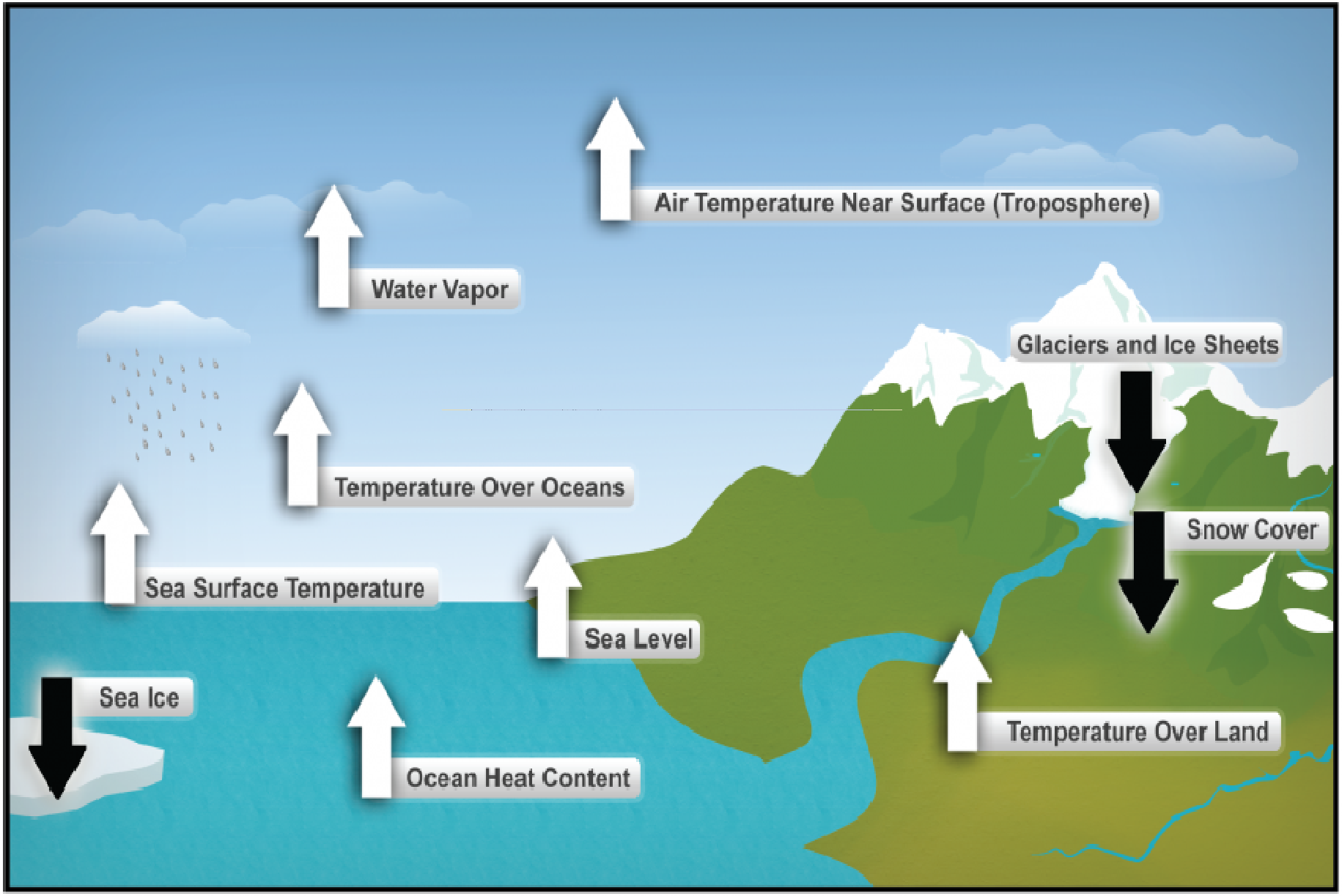
Climate change – statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer).



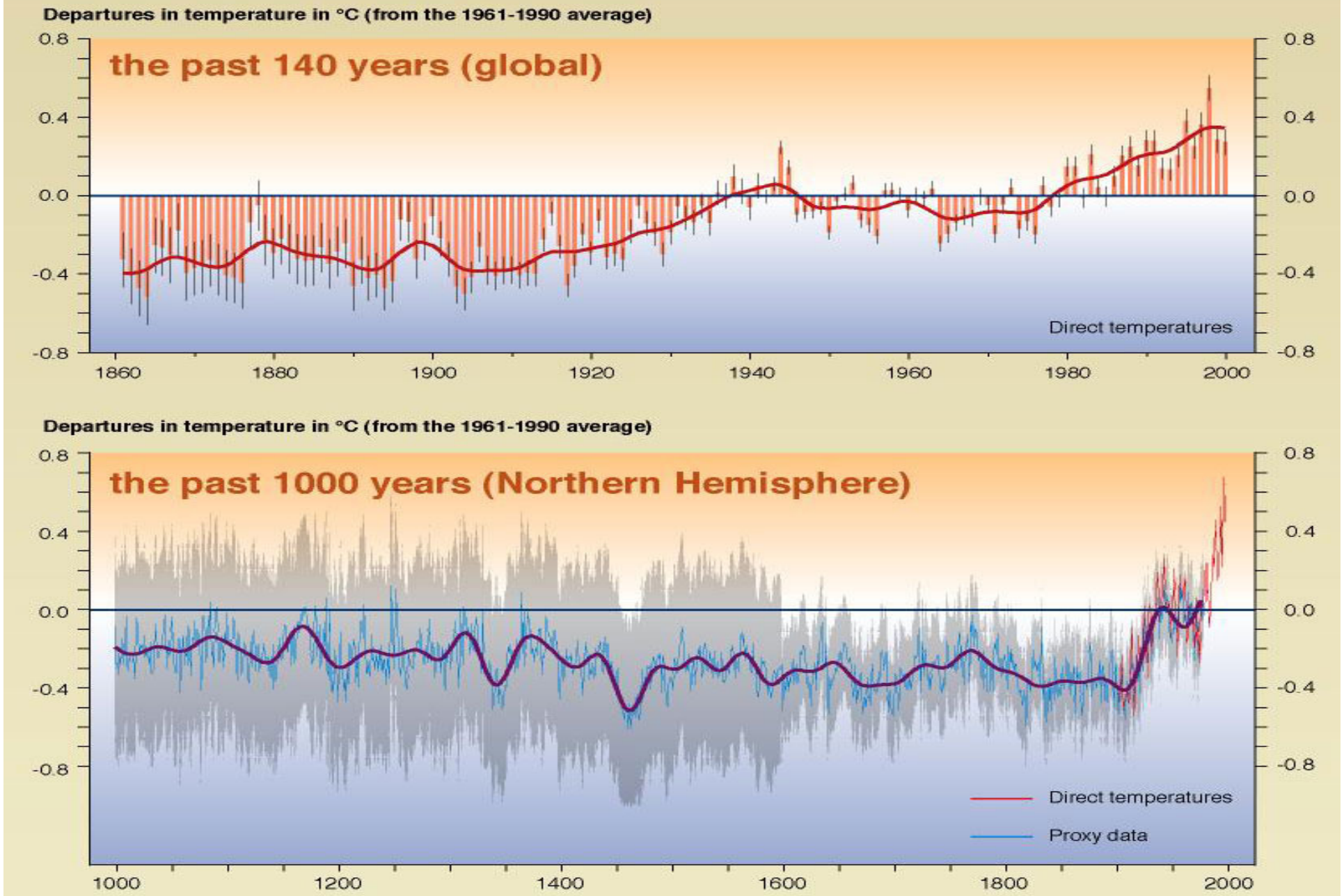
Time scales applicable to weather, climate variability and climate change



Ten Indicators of a Warming World

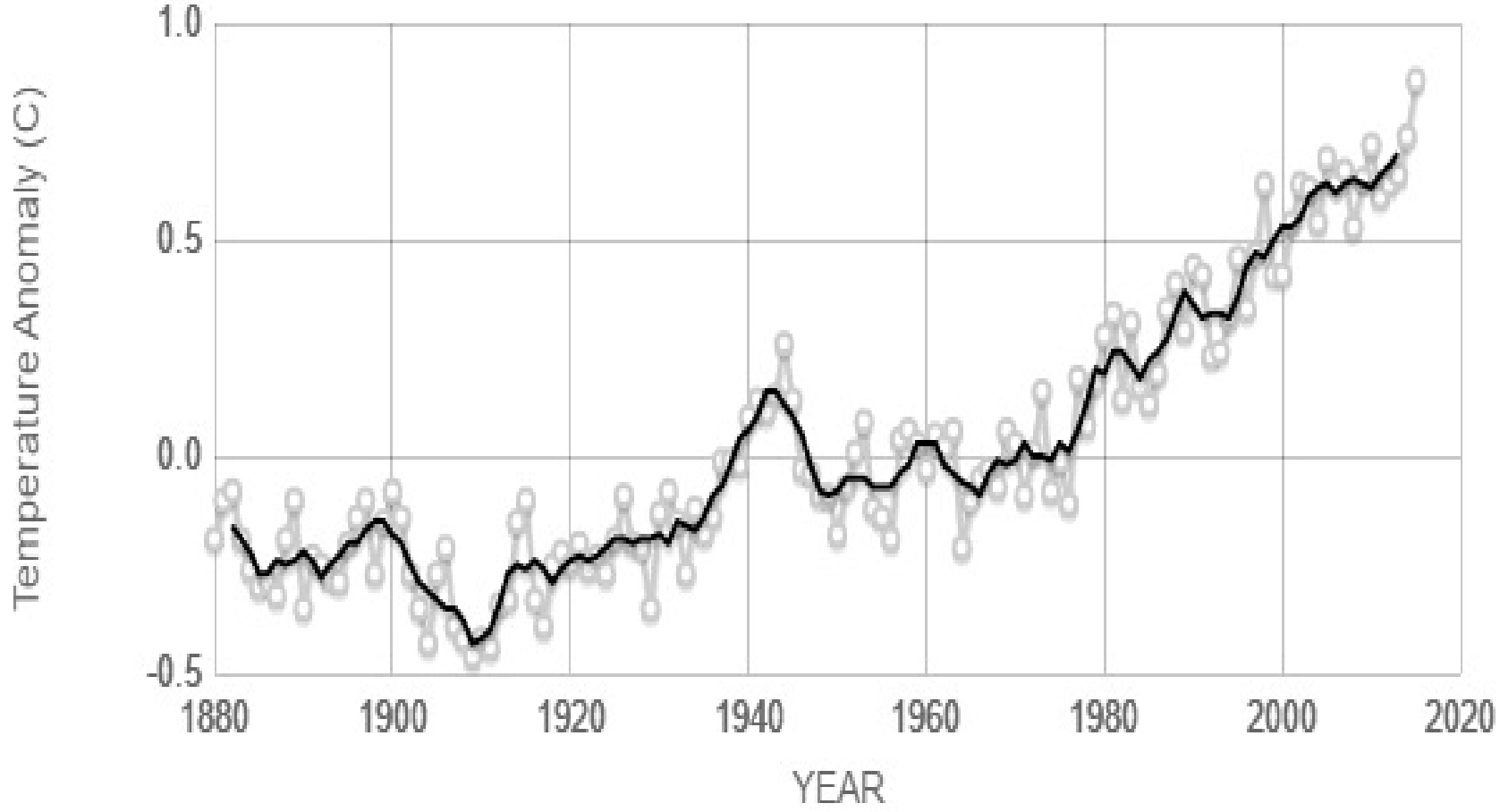


Variations of the Earth's surface temperature for...



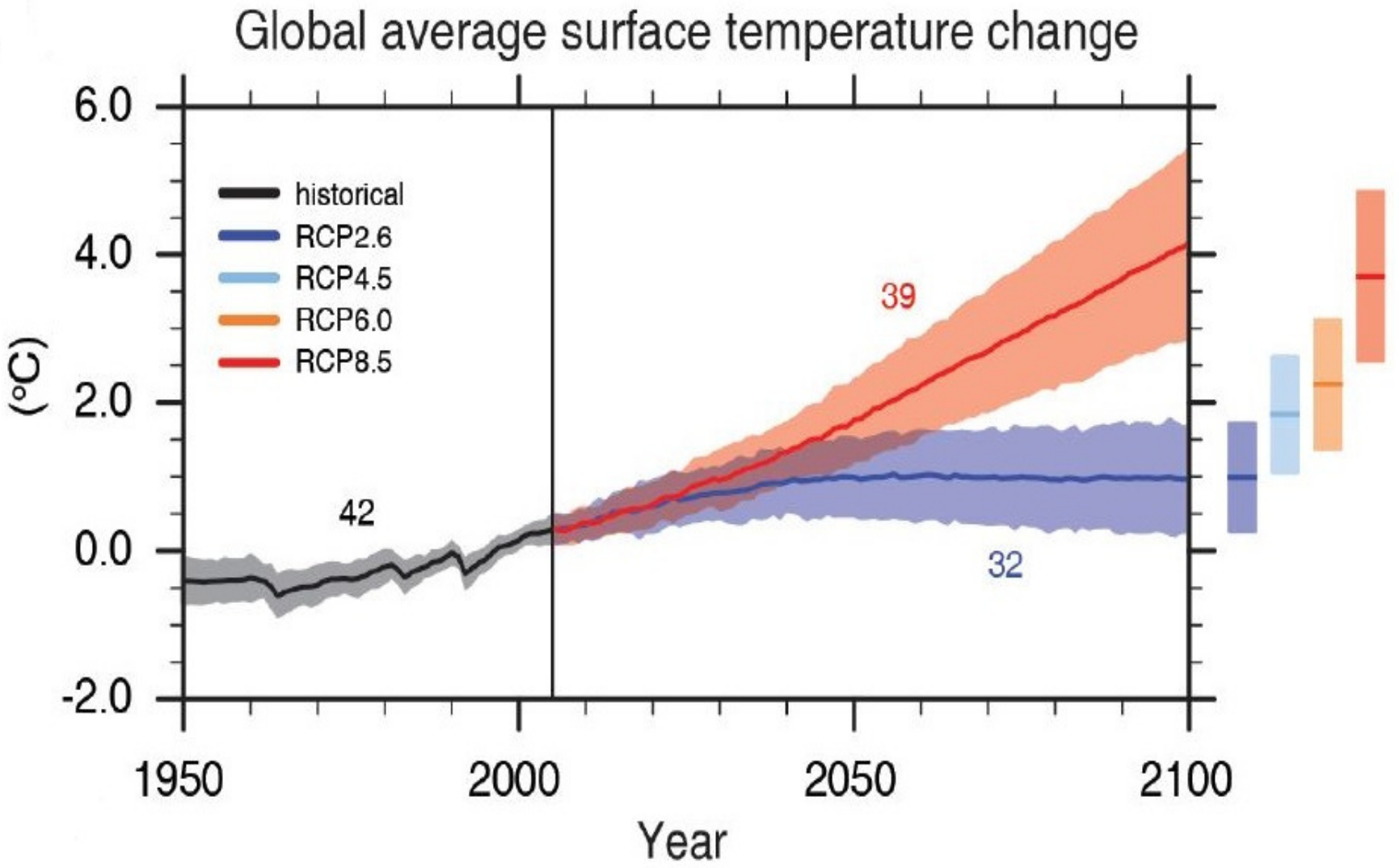
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

Variation of global surface temperature anomaly relative to 1951-1980 average temperatures



Source: climate.nasa.gov

Future temperature development in different emissions scenarios



Agriculture sector in India

- Agriculture is the main source of livelihood for almost 60 % of the country's total population.
- The impacts of climate change on agriculture will be severely felt in India.
- It has been projected that under the scenario of a 2.5 °C to 4.9 °C temperature rise in India, rice yields will drop by 32 %-40 % and wheat yields by 41 %-52 %.
- This would cause GDP to fall by 1.8 % to 3.4 % .
- The rural people are more vulnerable to climate variability and changes owing to their heavy dependence on agriculture for food and livelihood.
- For preparing people to face these challenges, decision-makers and policy planners need information on climate change.
- A close assessment of the vulnerability i.e., the degree to which agriculture is susceptible to the adverse effects of climate change, including climate variability and extremes is needed to allocate resources effectively and reduce the impacts

Role of different weather parameters in crop production

- Rainfall drives water availability and determines Sowing time (rainfed crops)
- Temperature drives crop growth, duration; influences milk production in animals and spawning in fish
- Temperature, RH influence pest and diseases incidence on crops, livestock and poultry
- Radiation influences the photosynthetic productivity
- Wet & dry spells cause significant impact on standing crops, physiology, loss of economic products (eg. fruit drop)
- Extreme events (eg. high rainfall/floods/heat wave/cold wave/cyclone /hail/frost) cause enormous losses of standing crops, live stock and fisheries

IMPACTS OF CLIMATE CHANGE

By **2030**, nine out of 10 of the major crops will experience reduced or stagnant growth rates, while average prices will increase dramatically as a result, at least in part, due to climate change.

MAIZE

12%

GROWTH RATE DECREASE

90% PRICE INCREASE

RICE

23%

GROWTH RATE DECREASE

89% PRICE INCREASE

WHEAT

13%

GROWTH RATE DECREASE

75% PRICE INCREASE

OTHER CROPS

8%

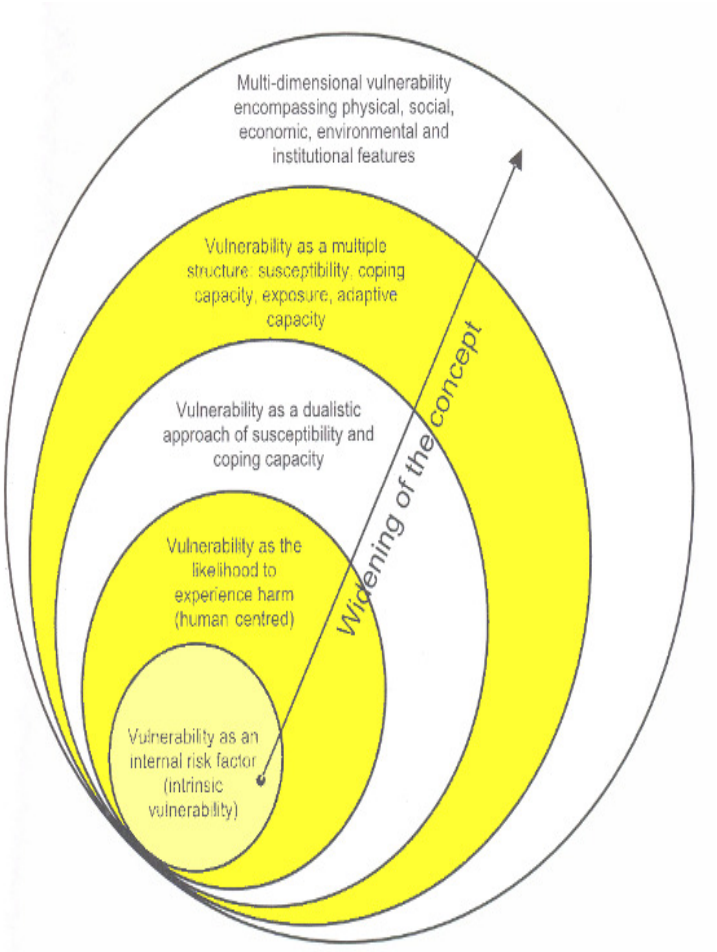
GROWTH RATE DECREASE

83% PRICE INCREASE

Climate Change Impacts on Agriculture

Biophysical impacts	Socio-economic impacts
• Physiological effects on cultivated crops, pasture, forests, fish, rangeland and livestock (quantity and quality) • Changes in the quantity and quality of land, soil and water resources • Increased weed and pest challenges, alien invasive species • Sea level rise, changes to ocean salinity • Sea temperature rise causing fish to inhabit different ranges	• Changes in yields and production • Reduced gross domestic product (GDP) from agriculture in the long term • greater fluctuations in world market prices • Changes in geographical distribution of trade • Increased number of people at risk of hunger and food insecurity • Migration and civil unrest

What is VULNERABILITY ????



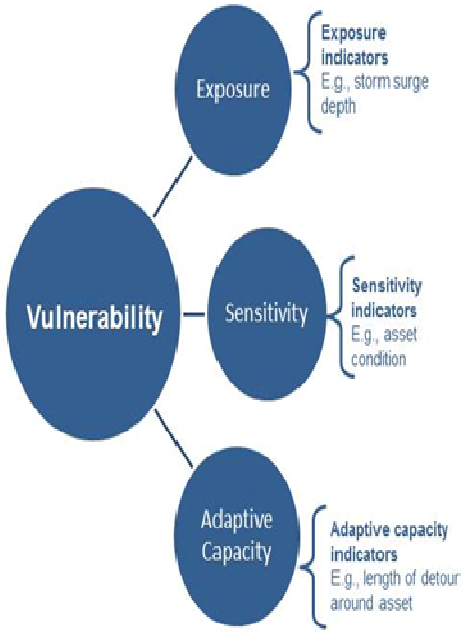
- The concept of vulnerability originated from the social sciences in response to the pure hazard oriented perception of disaster risk in the 1970s.
- "The degree of loss to a given element at risk or set of elements at risk resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total damage)" (UNDRO, 1991)
- Since that time different disciplines are working with the concept of vulnerability and the concept of vulnerability has broadened

Multiple definitions and different conceptual frameworks of vulnerability exist, because several distinct groups have different views on vulnerability.

Vulnerability

Vulnerability may be defined as a degree to which a system is susceptible to, or unable to cope with adverse effects of climate change, including climate variability and extremes (IPCC, 2007).

Components of vulnerability in the climate change context



Exposure- 'the nature and degree to which a system is exposed to significant climatic variations and it relates to climate stress upon a particular unit of analysis.

Sensitivity - 'the degree to which a system is affected, either adversely or beneficially, by climate related stimuli'. It is determined by demographic and environmental conditions of the region concerned.

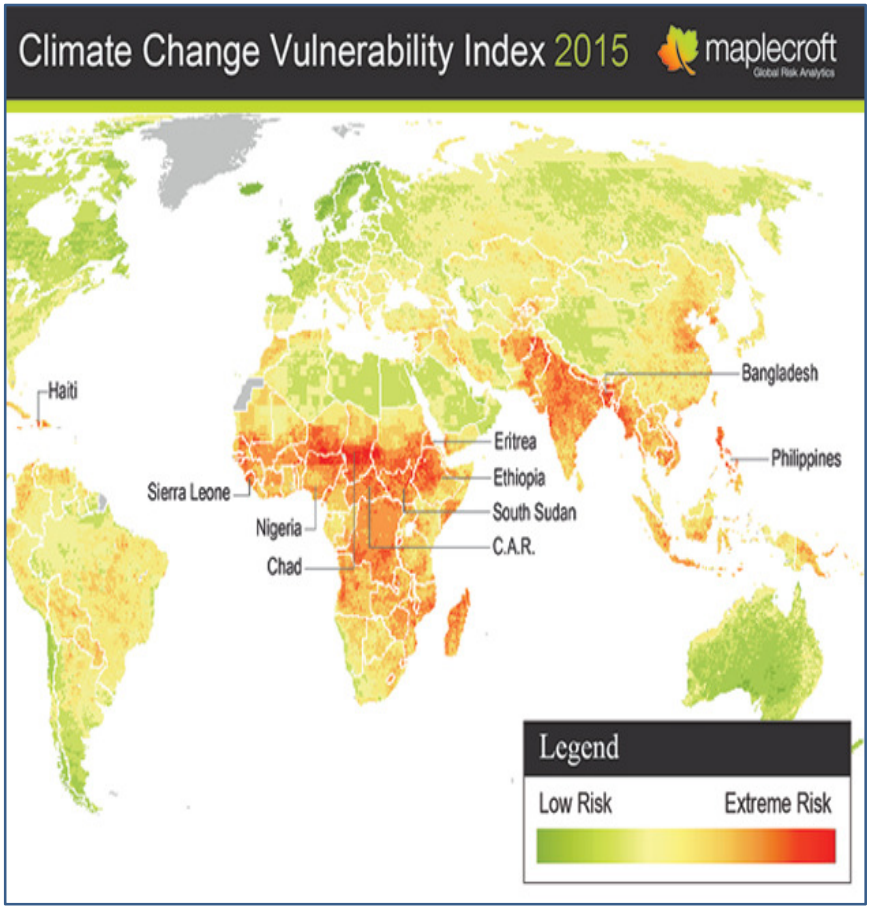
Adaptive capacity - 'the ability of a system to adjust to climate change, including climate variability and extremes to moderate potential damages, to take advantage of opportunities, or to cope with the consequences

Climate Change Vulnerability Index (CCVI)

Developed by global risks advisory firm Maplecroft, which enables organizations to identify areas of risk within their operations, supply chains and investments.

It evaluates 42 social, economic and environmental factors to assess national vulnerabilities across three core areas. These include-

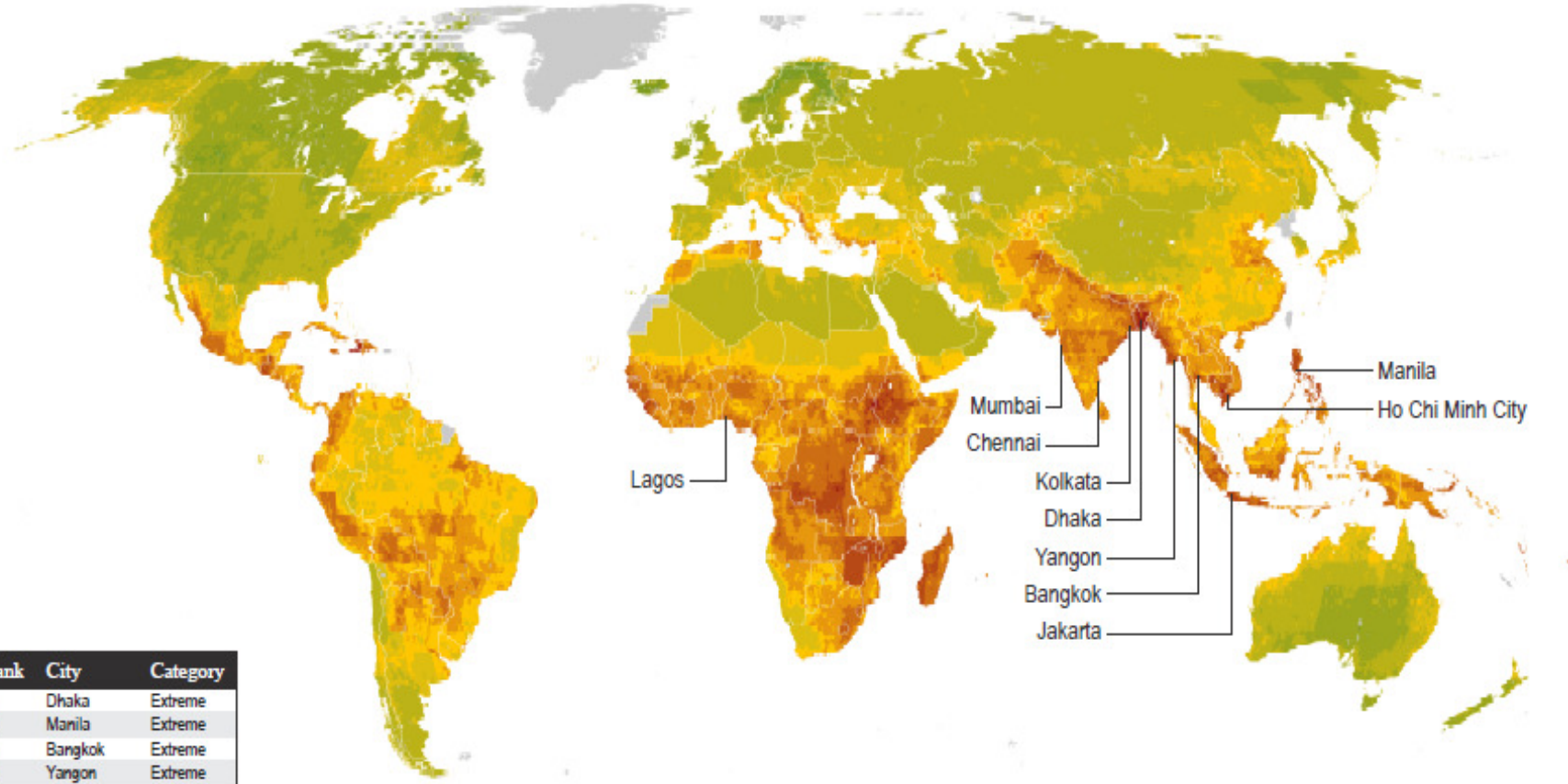
1. exposure to climate-related natural disasters and sea-level rise
2. human sensitivity in terms of population patterns, development, natural resources, agricultural dependency and conflicts
3. future vulnerability by considering the adaptive capacity of a country's government and infrastructure to combat climate change.



Most climate vulnerable cities

Climate Change Vulnerability Index 2013 – Most at risk cities

maplecroft

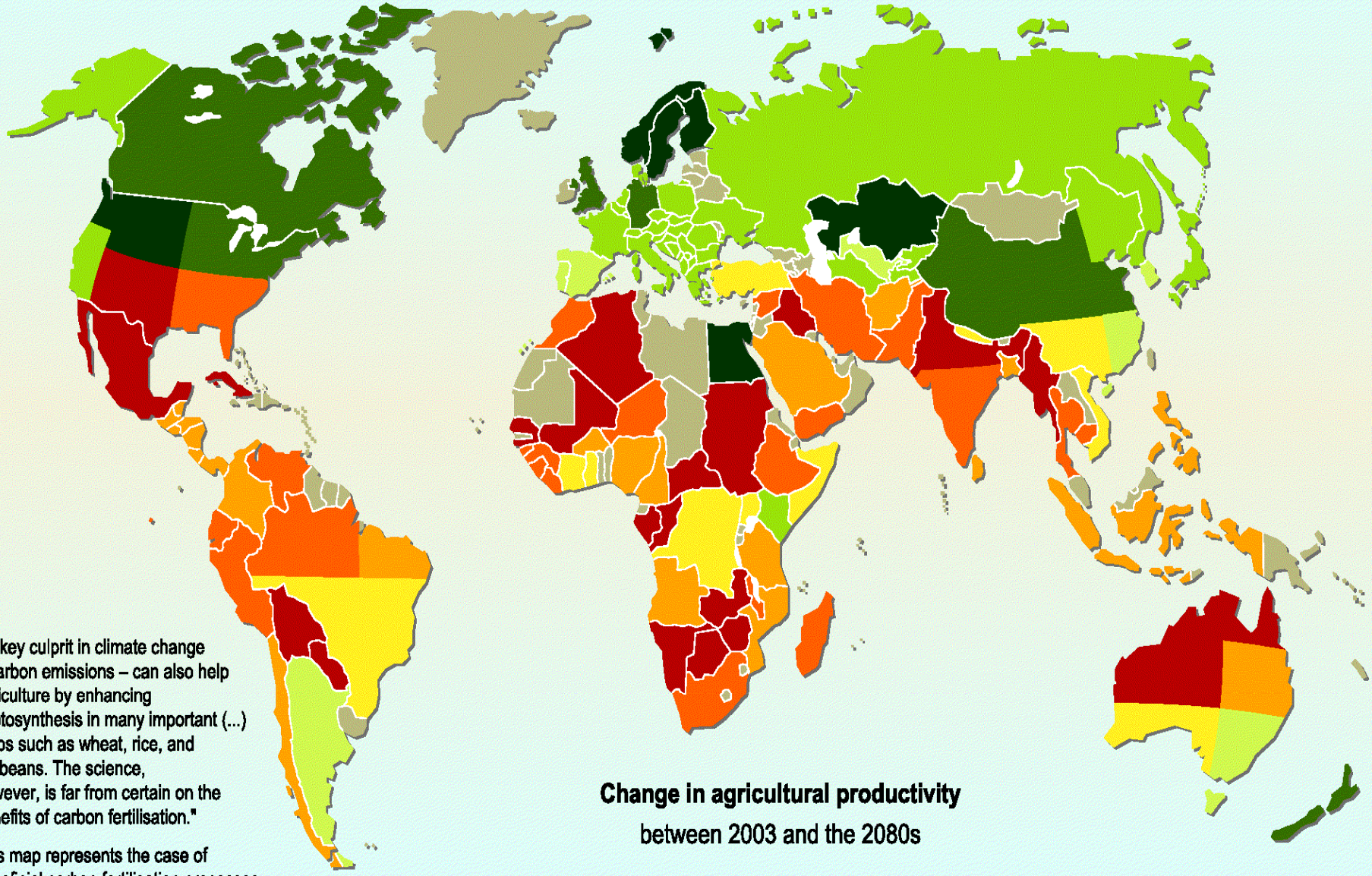


Rank	City	Category
1	Dhaka	Extreme
2	Manila	Extreme
3	Bangkok	Extreme
4	Yangon	Extreme
5	Djakarta	Extreme
6	Ho Chi Minh	Extreme
7	Kolkata	Extreme
8	Mumbai	High
9	Chennai	High
10	Lagos	High

Legend

Low Risk — Extreme Risk

Projected impact of climate change on agricultural yields

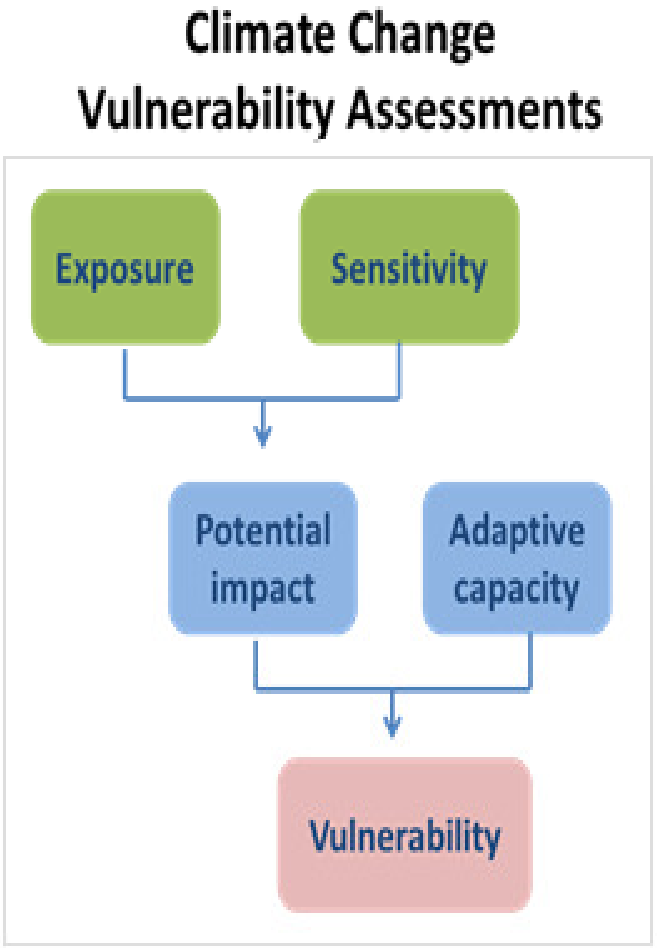


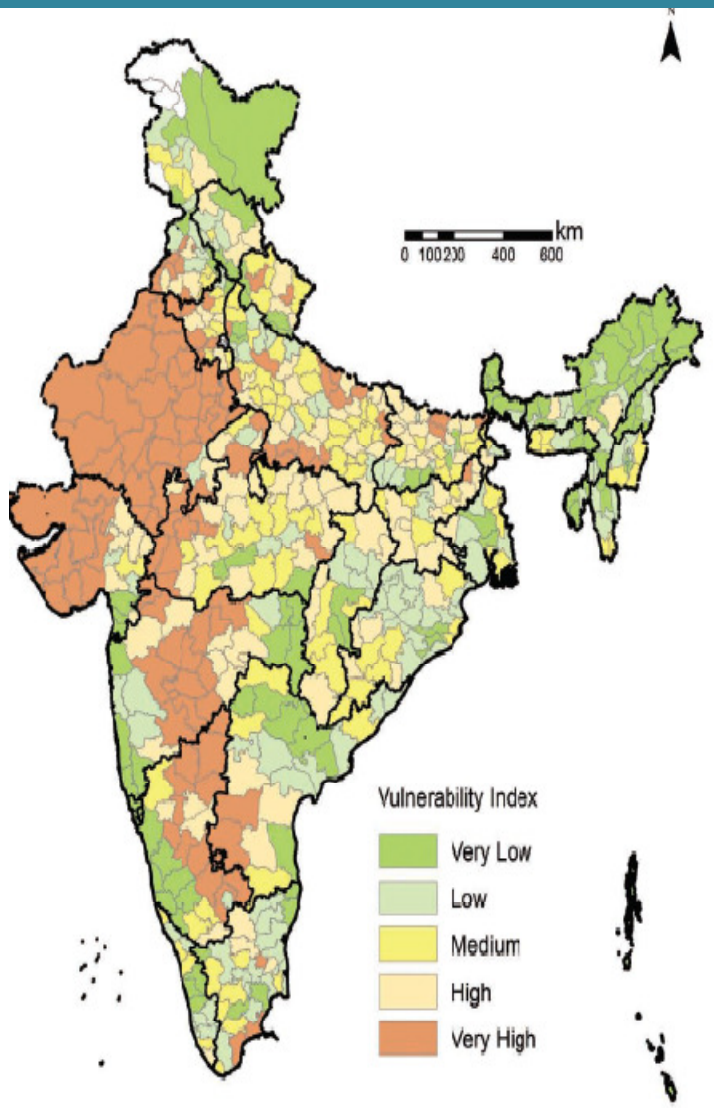
" A key culprit in climate change – carbon emissions – can also help agriculture by enhancing photosynthesis in many important (...) crops such as wheat, rice, and soybeans. The science, however, is far from certain on the benefits of carbon fertilisation."

This map represents the case of beneficial carbon fertilisation processes.

Source: Cline W., 2007, *Global Warming and Agriculture.*

Vulnerability of agriculture to Climate Change in different districts of India

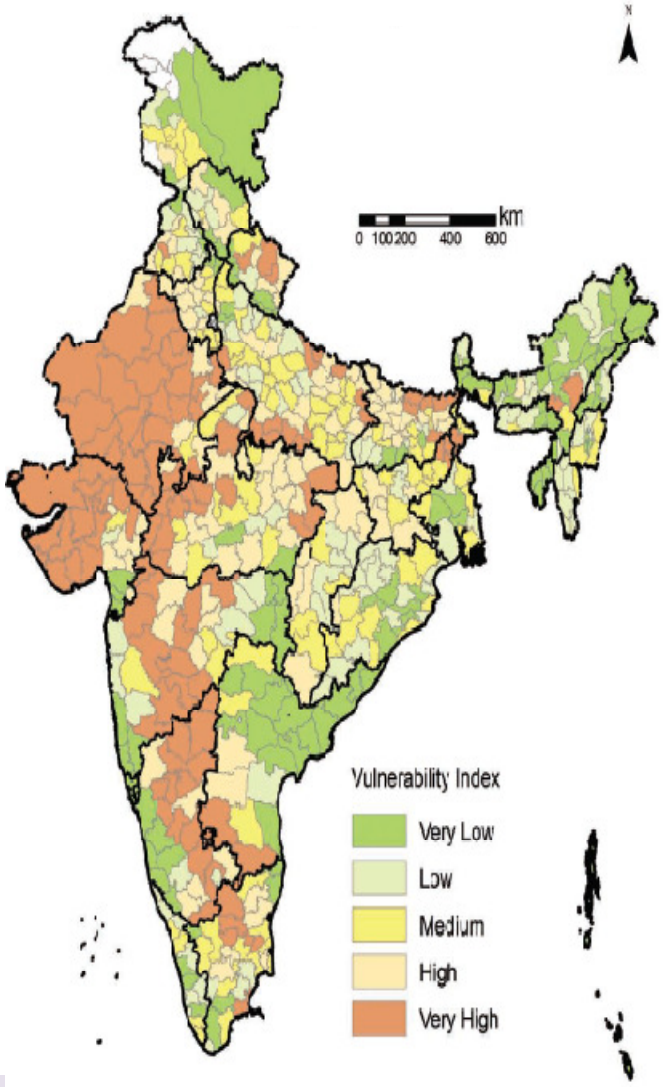




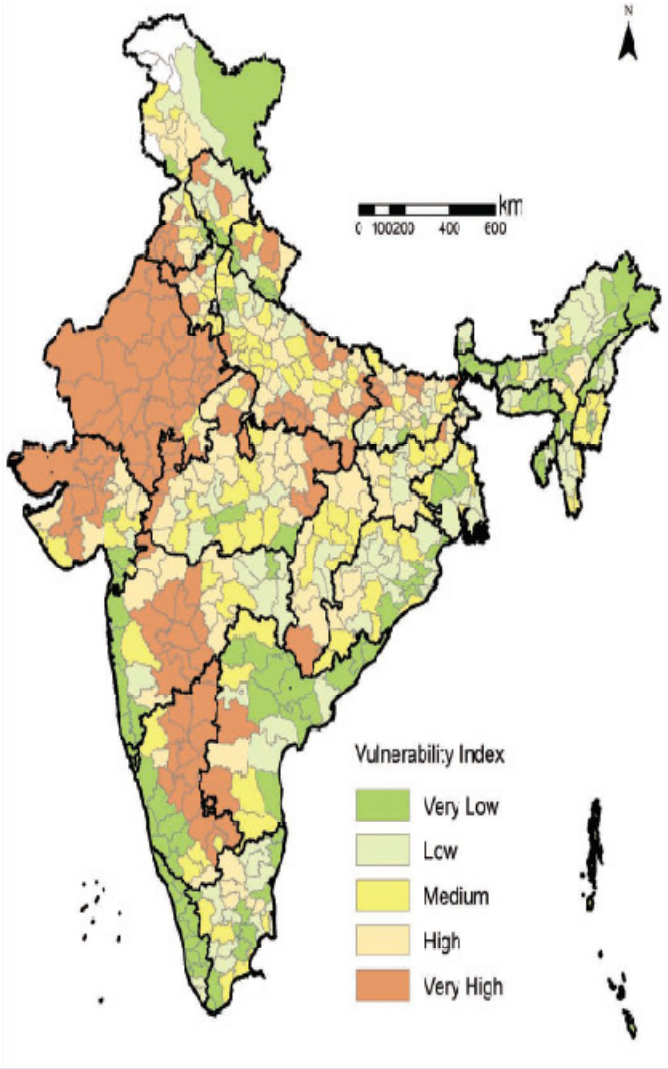
Source : Rama Rao C A, Raju B M K, Subba Rao A V M, Rao K V, Rao V U M, Kausalya Ramachandran, Venkateswarlu B and Sikka A K (2013) Atlas on Vulnerability of Indian Agriculture to Climate Change. Central Research Institute for Dryland Agriculture, Hyderabad P 116.

Vulnerability of agriculture to Climate Change in Future Scenario for different districts in India

(2021-2050)



(2071-2098)



Source : Rama Rao C A, Raju B M K, Subba Rao A V M, Rao K V, Rao V U M, Kausalya Ramachandran, Venkateswarlu B and Sikka A K (2013) Atlas on Vulnerability of Indian Agriculture to Climate Change. Central Research Institute for Dryland Agriculture, Hyderabad P 116.

Policy options for adaptation in agriculture

Policy option	Potential impacts and target points
Promote agricultural research	• Developing crop and livestock technologies (e.g. better heat and drought-resistant crops) • Enhancing seed banks • Encouraging the transfer or adoption of locally important innovations (e.g. water harvesting systems) • Making use of complementarities between public and private agricultural research
Promote crop and livestock diversification and agrobiodiversity	• Avoiding monocultures • Reducing the risk of crop failure (e.g. by advising farmers to grow drought-resistant food crops such as cassava, millet, or sorghum)
Promote adoption of technologies	• Modernising farm operations • Using adapted seeds
Increase efficiency of water infrastructure and water use	• Providing opportunities to reduce direct dependence on natural factors such as precipitation and runoff and reduce vulnerability to climatic variations and natural disasters • Improving irrigation systems

Contd

Policy options for adaptation in agriculture

Policy option	Potential impacts and target points
Disperse information on conservation management practices	• Protecting fields from water and wind erosion • Using management practices that reduce dependence on irrigation in order to decrease water consumption without reducing crop yields • Changing tillage practices (e.g. zero tillage on formerly overused/ depleted land)
Provide agricultural extension services	• Improving knowledge on agricultural crop and livestock management and on drought and flood management Promote investments in agriculture
Promote investments in agriculture	• Increasing agricultural productivity • Improving management practices
Promote investment in better information & forecasts	• Improving communication technologies in order to improve access to and handling of information • Refining modelling techniques that bring high-quality short-term forecasts to many parts of the world • Supporting the diffusion of information to help interpret forecasts in terms of their agronomic and economic

Adaptation options at farm level

Climatic/ landscape zone	Arid and semi-arid	Humid	Coastal areas	Mountain areas
Cropping systems				
Examples for inputs: new and adapted varieties	• Drought-tolerant crops (such as millet instead of corn) and varieties	• Early maturing varieties	• Salt-tolerant varieties	• Crop diversification, e.g. off-season crops, short-season crops, fruit cultivation
Crop management	• Enhancing crop rotation practices • Changing cropping patterns	• Improving seed storage	• Integrating trees and bushes to reduce water runoff and erosion and to provide flood protection	• Maintaining agrobiodiversity to conserve frost-tolerant species and varieties • Applying soil and water conservation measures, e.g. contour cropping and terracing

Adaptation options at farm level

Climatic/ landscape zone	Arid and semi-arid	Humid	Coastal areas	Mountain areas
Livestock systems				
Examples for inputs	• Using supplementary feeds and concentrates	• Using adapted livestock breeds	• Constructing livestock shelters	• Using supplementary feeds
Animal management	• Continuously matching stock rates with pasture production • Changing grassland cutting frequency • Restricting extensive livestock farming	• Enhancing animal welfare, e.g. vaccinating animals to protect them and reduce the spread of disease	• Moving herds from waterlogged fields	• Continuously matching stock rate with pasture production • Increasing feed reserves • Designating special areas for livestock grazing • Protecting steep slopes by avoiding overgrazing so that that the vegetation cover remains stable

Short-term adaptation options and policies

Adaptation option	Supporting policies
Crop insurance to protect against risk	Improve access, risk management, revise pricing
Crop / livestock diversification to increase productivity and protect against diseases	Availability of extension services, financial support
Adjust timing of farm operations to reduce risks of crop damage	Extension services, pricing policies
Change cropping intensity	Improved extension services, pricing policy adjustments
Livestock management to adjust to new climate conditions	Provision of extension services
Changes in tillage practices	Extension services to support activities, pricing incentives
Food reserves and storage as temporary relief	Improving access and affordability, revising pricing
Changing crop mix	Improving access and affordability, revising pricing, etc.
Modernisation of farm operations	Promote adoption of technologies
Permanent migration to diversify income opportunities	Education and training
Defining land-use and tenure rights for investments	Legal reform and enforcement

Long-term adaptation options and policies

Adaptation option	Supporting policies
Development of crop and livestock technology adapted to climate change stress: drought and heat tolerance	Agricultural research (crop and livestock trait development), agricultural extension services
Develop market efficiency	Invest in rural infrastructure, remove market barriers, property rights
Irrigation and expansion of water storage facilities	Public and private sector investment
Efficient water use	Water pricing reforms, clearly defined property rights
Promoting international trade	Pricing and exchange rate policies
Improving forecasting mechanisms	Information needs to be distributed across all sectors
Institutional strengthening and creating decision-making structures	Reform existing institutions connected with agriculture

Conclusion

There is immense potential in agroforestry systems to enhance productivity and sustainability of agricultural lands or the land resources which have never been put into service due to so many factors, can be better used by adopting different agroforestry practices like intercropping of ginger and turmeric in it [Agrisilvi, Agrihortisilvi, Agrosilvipastoral(Home gardens) and Agri-hortipastoral systems] for high remuneration and useful combination(age and spacing of tree species) if properly managed (with recommended agronomic &/or silvicultural practices for particular region) could increase the production potential sufficiently. Hence, such systems need to be made popular among farmers for sustainable livelihood.

Various agroforestry systems like, silviagriculture, Agri-horti-pastoral, silvihortipastoral system contributed significantly in enhancing the physical and chemical property of soil especially the top soil through effective recycling of nutrients. The overall improvement in the physical properties of soil is suggestive of role of agroforestry systems for sustainable land use keeping in view the various parameters of climate change and objectives of doubling the farmer's income in India.

THANK YOU

FOR YOUR

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ATTENTION