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Contrasting resilience of agriculture to climate change in coastal and non-coastal districts of Odisha

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ABSTRACT

The issue of climate change impact on agriculture and its mitigation through developing resiliency is of prime importance to enhance farmers' income and livelihood security. A study was conducted in Odisha to find out contrast in resilience of agriculture to climate change in coastal and non-coastal district. Agricultural scenario was studied through a composite agricultural scenario index (ASI) during 2001 to 2014.The coastal district Balasore showed a relatively better resilience in the years of climatic disasters maintaining the ASI value at a higher level as compared to non-coastal district Khurda due to better agricultural and irrigation water resources scenario in Balasore district. However, Balasore is more vulnerable than Khurda in all the seasons; vulnerability of Balasore and Khurda districts is found highest in monsoon and pre-monsoon period, respectively. About 90 percent of sampled farm households possess irrigated land in Balasore district and rainfed land in Khurda district. A remarkable dent in crop productivity is seen during calamity years, which are more severe in Khurda district during heat waves and cyclone than Balasore district, which faces a decline during cyclone and flood.

Key words: Agriculture, Climate change events, Irrigation, Resilience, Socio-economy, Vulnerability

Climate change has significant implications on the coastal population and agricultural performance. According to India's National Communication (NATCOM) to the United Nations Framework Convention on Climate Change (UNFCC) report (2004), variety of impacts are expected which include land loss and population displacement, increased flooding of low-lying coastal areas, agricultural impacts (like, loss of yield and employment) resulting from inundation, salinization, and land loss, impacts on coastal aquaculture. United Nations Environment Programme (UNEP 1989) identified India among the 27 countries that were having vulnerable coastline which is low-lying, densely populated (average population density of 455 persons per square km, which is about 1.5 times the national average of 324 as per Census 2011). Climate change is often a concern along the east coast of India in view of the damages that occur from the cyclones from in the Bay of Bengal. The 1999 tropical cyclone that hit Odisha demonstrated the extreme significance of impacts on coastal agro-ecosystem. If we look at examples of the countries with coastal agro-ecosystem, it is often reported that institutional constraints limit entitlements and access to resources for communities in coastal region and thereby increase vulnerability.

There are vast sectoral and regional variations in India that affect the resilience to climate change. For instance, irrigation coverage is above three-fourths of total cultivated area in Punjab, while in Odisha it is less than a quarter. Farmers in Odisha are more dependent on the monsoon than others, thus more vulnerable to climate change. Various coastal districts of Andhra Pradesh and Odisha are ranked as highly vulnerable on a vulnerability index developed by Patnaik and Narayanan (2005).

A system with higher adaptive capacity will be more resilient to disturbance. On the other hand, systems are considered to be vulnerable if they have low resilience and are greatly impacted by climate change events (Smit and Wandel 2006). Rao *et al.* (2016) mentioned that resilience through adaptation is as important as mitigation, when dealing with climate change. According to Ghosh *et al.* (2017), the issue of climate change and its impact on agriculture as well as mitigation through developing resiliency is of prime importance in present and future years. It is imperative to understand the impacts of climate change on cropping scenario and the vulnerability level in and across agricultural households for India in general, and for eastern coastal part of the country in particular (Narayanan and Sahu 2016). On this backdrop, present study was conducted to find out contrast in resilience of

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agriculture to climate change in coastal and non-coastal districts of Odisha.

MATERIALS AND METHODS

Odisha is one among the Indian states which has the highest proportion of poor persons in its population. On the other hand, being on the bank of Bay of Bengal, the state is exposed to the vagaries of climatic change. Therefore, Odisha was purposively chosen for present study.A coastal district, Balasore was selected as the district is characterized by fragile environment and prone to flood and cyclone, low and highly variable rainfall, high water deficiency, frequent rainfall failure, etc. The area is intersected by a network of rivers and the Bay of Bengal on the eastern side making it flood prone. And to compare the above stated climatic vagaries and a variable ecosystem, a non-coastal district of Odisha, Khurda was also covered that mainly suffers from drought and heat wave.

To depict the agricultural scenario, a composite Agricultural Scenario Index (ASI) was constructed for each of the years starting from 2001-02 to 2013-14, considering nine parameters, which were percentage of cultivable land to total land area, percentage of net sown area to total cultivable area, percentage of net irrigated area to net sown area, percentage of food grain area to gross sown area, food grain productivity, percentage of area under major crop to gross sown area, productivity of major crop, cropping intensity and fertilizer consumption. It was assumed that higher the ASI value, better the resiliency showed by a district in a calamity year as compared to other districts suffered the same event.

Different indices were constructed for assessment of irrigation scenario, viz. Groundwater Development Index (GWDI), Irrigation Coverage Index (ICI) and Composite Irrigation Index (CII). The data on irrigation parameters corresponded to triennium 2013-14 (average of three years data, 2011-12, 2012-13 and 2013-14, to have a near appropriate irrigation resource scenario in the area).GWDI considered gross annual draft (ha-m) out of utilisable groundwater resource (ha-m). ICI was calculated on the basis of net irrigated area out of net cultivated area.CII was calculated averaging GWDI and ICI giving equal weight. It was assumed that higher the irrigation index values, better the agricultural scenario and its resiliency in a calamity year as compared to other districts suffered the same event.

Socio-Economic Index (SEI) was calculated on the basis of parameters, viz. percentage of population below poverty line, percentage of scheduled cast (SC) and scheduled tribe (ST) population, percentage of urban population to total population, literacy rate, female work participation rate, percentage of agricultural laborers to total workers, percentage of cultivators to total workers, percentage of industrial workers to total workers, and percentage of main workers to total population. The data were taken from Census of India 2011.It was assumed that higher the SEI value, better the resiliency of agriculture to climate change events showed by a district in a calamity year as compared to other districts suffered the same event.

Climatic Vulnerability Index (CVI) was calculated taking mean value over the study period (2001-02 to 2013-14) for four seasonal periods (Winter, Pre-monsoon, Monsoon and Post-monsoon). The parameters considered were: mean minimum temperature, mean maximum temperature and mean deviation in rainfall.Winter includes months of January and February, pre-monsoon season considers March to May, monsoon season comprises of June to September and post-monsoon period takes into consideration October to December.

The primary indexing for each of the above-mentioned parameters under respective index is done by following formula.

Primary index for the positive parameter is calculated as: (actual value of the parameter in selected district - minimum value of the parameter among all districts of Odisha) / (maximum value of parameter - minimum value of parameter)

For the negative parameter (eg. poverty, SC/ST population, etc), index is calculated as: (maximum value of the parameter among all districts of Odisha- actual value of the parameter in selected district) / (maximum value of parameter - minimum value of parameter)

Composite index like ASI, CII, SEI, CVI were derived by averaging the primary index values of all the parameters under respective composite index.

As per the objectives of the study both secondary and primary data were collected. Secondary level data were considered to work out resiliency of agriculture to climate change in selected districts.

Primary data collection in both Balasore and Khurda districts followed simple random sampling method through selection of two blocks under each district and two villages under each block and 15 farm households under each village. Thus, overall four blocks, eight villages and 120 farm households, 60 each from selected two districts included in the study.

RESULTS AND DISCUSSION

The comparative agricultural scenario of Balasore and Khurda districts is depicted in Fig 1. It is visible that the agricultural scenario in Balasore district is better than Khurda during study years. The maximum and minimum ASI value showed the fluctuations during study period that may be attributed to the climatic aberration. A comparison of the minimum and maximum value of ASI show the extent of resilience of agriculture in that given district; accordingly, the coastal district Balasore have showed a relatively better resilience maintaining the ASI value at a higher level as compared to Khurda district of Odisha during the calamity years. The ASI value is ranged from 61.2 (2012-13) to 78.3 (2011-12) in Balasore and from 44.4 (2003-04) to 57.9 (2006-07) in Khurda district.

Comparative irrigation scenario of Balasore and Khurda districts indicates the better irrigation regime in Balasore that may be attributed to the fact of better groundwater utilization in Balasore district.

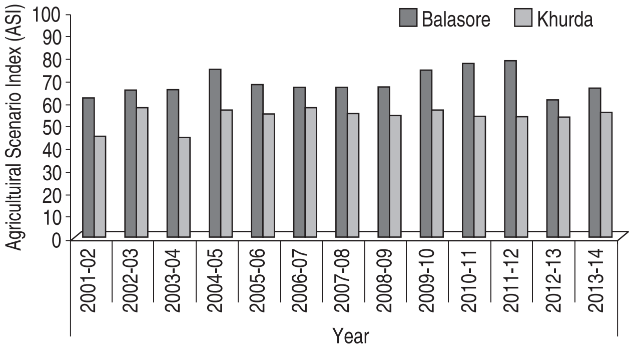

Fig 1 Comparative Agricultural Scenario in Balasore and Khurda Districts of Odisha.

Climatic vulnerability in the selected districts is worked out for four climate seasons, viz. winter (January and February), pre-monsoon (March to May), monsoon (June to September) and post-monsoon (October to December). The district wise and season wise climatic vulnerability index (CVI) values developed on the basis of pooled mean data of study period, which depict more vulnerability of Balasore district. The vulnerability is found more during monsoon and post-monsoon period in Balasore district; while it is more during pre-monsoon period in Khurda district.

The agriculture, irrigation, socio-economic and climate scenario is compared in Table 1. It is evident that Balasore district, inspite of more climatically vulnerable and socio-economically inferior as compared to Khurda district showed better agricultural scenario. It is worth mentioning here that the significance of irrigation in general and groundwater irrigation in particular is the reason behind more resilience in agriculture in Balasore, a coastal district. Better groundwater irrigation regime has facilitated a better agricultural performance even in a calamity year in Balasore district. This differential agricultural scenario in the coastal district of Odisha may be attributed to the fact of higher the ASI value, better the resiliency showed by a district in a calamity year as compared to other districts suffered the same event.

The linkage is evident between agriculture and irrigation;

Table 1 Agriculture, Irrigation, Socio-economy and Climatic Scenario in Balasore and Khurda districts of Odisha

Index	Balasore	Khurda
ASI	66.30	55.30
GWDI	88.00	48.00
ICI	39.00	31.00
CII	64.00	40.00
SEI	47.31	56.41
CVI Winter	43.21	30.76
CVI Pre-monsoon	57.56	42.66
CVI Monsoon	78.06	22.21
CVI Post monsoon	62.33	22.65

however, the same is not evident between agricultural and socio-economic scenario. Socio-economic scenario is found at medium level. Thus, district's socio-economic situation is yet to be influenced by agriculture that makes the impact of climatic vulnerability further important. Seasonal climatic vulnerability index depicts relatively more vulnerability of coastal districts during monsoon and post-monsoon seasons. With increasing climatic vulnerability, it becomes more challenging to improve upon the socio-economic condition to increase the resilience of farm households towards climate change events.

Patwardhan *et al.* (2003) reported that eastern coast of India is more vulnerable than the western coast with respect to the frequency of occurrence of extreme events like cyclones and depressions. Patnaik and Narayanan (2005) built a vulnerability index and ranked the various coastal districts of highly vulnerable states (Andhra Pradesh and Odisha) in terms of their performance on the index; according to which coastal districts of Odisha are found more vulnerable. This is inconformity with findings of present study.

According to a study conducted by Bahinipati (2014), most of the districts in Odisha are prone to both cyclones and floods. Three key observations emerged. First, components like sensitivity and adaptive capacity were found to act as the major determinants of vulnerability. Secondly, eight districts were found to have a higher vulnerability score, and surprisingly, some of the districts are non-coastal. Thirdly, factors like demography, agriculture and economic capacity emerged as the major cause for increasing vulnerability. Balasore, Bhadrak, Jajpur, Kendrapada, Malkangiri, Nabarangpur, Nuapada and Rayagada have vulnerability levels higher than the other districts of the state. Balasore, Bhadrak and Kendrapada are the coastal districts, while the remaining five districts are non-coastal districts.

The cultivable land particulars of sampled farm households in Balasore and Khurda districts of Odisha are presented in Table 2. In Balasore district, average rainfed and irrigated cultivable land as owned by the farm households is 1.82 and 1.55 acre, with standard deviation values 1.99 and 1.10, respectively. Average rainfed and irrigated leased in cultivable land is 0.40 and 0.86 acre with standard deviation values 0.16 and 0.59, respectively. Total average own land and leased in land of sampled farm households is 1.98 and 0.92 acre with standard deviation values 1.80 and 0.64, respectively. About 90 percent of sampled farm households have irrigated land. Sampled farm households in Khurda district stand with a mean rainfed and irrigated cultivable land at 2.24 and 1.21 acre with respective standard deviation values 1.35 and 0.39, respectively. Mean rainfed and irrigated leased in land is 1.23 and 1.20 acre with standard deviation values 0.98 and 1.13, respectively. Total average own land and leased in land of sampled farm households is 2.40 and 1.22 acre with standard deviation values as 1.30 and 0.92, respectively. Contrastingly, about 90 percent of sampled farm households have rainfed land. Thus, there is relatively more share of irrigated area in

Table 2 Cultivable land particulars of the households in Balasore and Khurda districts of Odisha

Land particular (acre)	Mean ± Standard Deviation (SD) Value					
	Balasore district (n=60)			Khurda district (n=60)		
	Rainfed	Irrigated	Total	Rainfed	Irrigated	Total
Own land	1.82±1.99 (n=15)	1.55±1.10 (n=53)	1.98±1.80 (n=60)	2.24±1.35 (n=54)	1.21±0.39 (n=10)	2.40±1.30 (n=60)
Leased in	0.40±0.16 (n=13)	0.86±0.59 (n=24)	0.92±0.64 (n=30)	1.23±0.98 (n=7)	1.20±1.13 (n=3)	1.22±0.92 (n=8)

n indicates number of farmers that is given in parenthesis

case of farmers of Balasore district; contrastingly, farmers of Khurda district have more area under rainfed condition.

Cropping pattern of Balasore and Khurda district in a normal year is indicated in Table 3. In Balasore, paddy is the major crop grown by the farmers (57 out of 60 selected farmers) in a mean area of 1.71 acres with a standard deviation of 1.39 in *kharif* season and 1.67 acres (28 farmers out of 60 farmers) with a standard deviation of 1.32 in *rabi* season with production of 35.93 q and 32.95 q, respectively. Vegetables are also grown by in *kharif* season covering only 0.50 acres with production of 22 q (5 farmers); while in *rabi* season mean area under vegetables is 0.66 acres with production of 14.88 quintal (20 farmers). Other crops grown by the farmer in *rabi* season are pulses (20) and oilseeds (13) with an average area of 0.88 acres and 0.35 acres, respectively and production of 2.84 q and 1 q, respectively. In Khurda district paddy is cultivated just once in a year as dominantly rainfed area unlike the coastal district of Balasore having groundwater irrigated area. The mean area under paddy crop in *kharif* season is 2.29 acres with standard deviation of 1.30 and production of 42.78 q with standard deviation of 27.72 (57 farmers). Vegetables are grown by the farmers (13) in an average area of 1.09 acres with production of 64 q.

The number of farmers growing crops and production falls when there is a deviation from normal year in the occurrence of climate change events. Table 4 indicates in a drought year in Balasore district, area and production under paddy crop is 1.83 acres and 32.23 q in *kharif* season with a higher standard deviation than the normal year in terms of area i.e. 1.45 (50 farmers grow paddy). Paddy is grown in 2.62 acres in dry season (13 farmers) with production of 42.70 q. The productivity of paddy is reduced in both seasons in a drought year. No crops were grown in *rabi* season by the farmers due to non-availability of water for irrigation due to the drought. The area and production under paddy crop in Khurda district are found 2.25 acres and 30.37 q, respectively, which have decreased as compared to the normal year. Though not a remarkable change in area under vegetables is seen i.e. about 1.60 acres but production level dropped for vegetable cultivation in drought year, i.e. 54 q with number of farmers growing vegetables narrowed down from 13 to 6 only.

Table 3 Cropping pattern in normal year in Balasore and Khurda districts of Odisha

District	Crops	*Kharif* season		*Rabi* season	
		Area (acres)	Production (q)	Area (acres)	Production (q)
Balasore (n=60)	Paddy (n= 57 in *kharif* season; n=28 in *rabi* season)	1.71 (1.39)	35.93 (15.73)	1.67 (1.32)	32.25 (26.19)
	Pulses (n=20)			0.88 (0.60)	2.84 (2.18)
	Oilseeds (n=13)			0.35 (0.21)	1.00 (0.00)
	Vegetables (n= 5 in *kharif* season; n=20 in *rabi* season)	0.50 (0.20)	22.00 (5.03)	0.66 (0.60)	14.88 (18.26)
Khurda (n=60)	Paddy (n=57)	2.29 (1.30)	42.78 (27.72)		
	Vegetables (n=13)			1.09 (0.85)	64.44 (45.31)

n indicates number of farmers; figure in the parenthesis indicates standard deviation value.

Table 4 Cropping pattern in drought year in Balasore and Khurda districts of Odisha

District	Crops	*Kharif* season		*Rabi* season	
		Area (acres)	Production (q)	Area (acres)	Production (q)
Balasore (n=60)	Paddy (n=50 in *kharif* season; n=13 in *rabi* season)	1.83 (1.45)	32.23 (32.93)	2.62 (1.24)	42.70 (21.49)
Khurda (n=60)	Paddy (n=56)	2.25 (1.31)	30.37 (21.80)		
	Vegetables (n=6)			1.60 (0.89)	54.00 (35.78)

n indicates number of farmers; figure in the parenthesis indicates standard deviation value.

Table 5 Cropping pattern in flood year in Balasore and Khurda districts of Odisha

District	Crops	*Kharif* season		*Rabi* season	
		Area (acres)	Production (q)	Area (acres)	Production (q)
Balasore (n=60)	Paddy (n=42 in *kharif* season; n=4 in *rabi* season)	2.04 (1.49)	12.82 (26.14)	2.03 (1.67)	16.67 (7.64)
Khurda (n=60)	Paddy (n=20)	1.78 (0.58)	22.25 (13.06)		
	Vegetables (n=3)			1.25 (0.35)	55.00 (7.07)

n indicates number of farmers; figure in the parenthesis indicates standard deviation value.

During a flood year, number of farmers growing paddy in Balasore district has decreased. Paddy is grown in mean area of 2.04 acres and 2.03 acres with production of 12.82 q and 16.67 q in *kharif* and *rabi* season, respectively. And the farmers could not grow any other crops during flood year in contrast to normal year (Table 5). In Khurda district both area and production go down in the flood year. Respective mean area under paddy in *kharif* season and vegetables in *rabi* season is 1.78 acres and 1.25 acres with corresponding mean production of 22.25 q and 55.00 q, respectively. The number of farm households growing both crops also has declined.

Cyclonic storms are the highest rated calamity in terms of degree of hardship for both the districts of Odisha. Evidently from Table 6, the number of farmers growing paddy and its production both decreased in comparison to a normal year and only single crop is taken up during the calamity period in Balasore district. The mean paddy area is 1.96 acres and production only 7.91 q in *kharif* season. In Khurda district, paddy is grown in *kharif* season in an average area of 2.34 acres and production of only 12.09 q. Mostly no crops are grown in *rabi* season in the event of cyclone which mostly happen during post-monsoon season.

It is evident that area under *kharif* season paddy during calamity years does not vary much; however, the productivity is significantly reduced in the event of calamities both in Balasore and Khurda district. The reduction in yield is maximum during cyclone year followed by flood year as observed from field survey of the sampled farmers during present study. Similar scenario also prevails in case of *rabi* season paddy. Drought does not affect the area and yield in *rabi* season paddy. In a normal year during *rabi* season, sampled farmers have grown vegetables, pulses and oilseeds in Balasore and vegetables in Khurda. However, farmers could not grow any crop other than paddy in the event of drought and flood in Balasore. Few farmers have cultivated vegetable crops in Khurda district during *rabi* season but productivity is decreased significantly. No crops are grown in *rabi* season if cyclone occurs.

Table 6 Cropping pattern in cyclone year in Balasore and Khurda districts of Odisha

District	Crops	*Kharif* season		*Rabi* season	
		Area (acres)	Production (q)	Area (acres)	Production (q)
Balasore (n=60)	Paddy (n=43)	1.96 (1.45)	7.91 (17.58)		
Khurda (n=60)	Paddy (n=49)	2.34 (1.29)	12.09 (13.78)		

n indicates number of farmers; figure in the parenthesis indicates standard deviation value.

Findings of present study conform to the past studies. According to O'Brien (2004), the districts with higher irrigation coverage had higher resilience and adaptive capacity in India. Districts with high production per unit area are presumed to be more resilient and less vulnerable than those with low production. A survey done by Sahu and Mishra (2013) suggests that people who have better access to irrigation facility they are adapting maximum of the possible adaptation options. People who do not adopt any of the techniques are those who do not have access to irrigation facility and have a very low level of income. Mahato (2014) reported that climate change's negative impact on agriculture, are severe which is projected to have a great impact on food production and may threaten the food security and hence, require special agricultural measures to combat with. Mishra and Sahu (2014) in a study in Kendrapara district of Odisha reported that access to irrigation, ownership of land and land size of the farmers positively influenced various adaptations strategies.

Agricultural scenario in a coastal and non-coastal district of Odisha was worked out through a composite agricultural scenario index for each of the years starting from 2001-02 to 2013-14. A comparison of the minimum and maximum value of ASI in a given district show the extent of resilience of agriculture in that given district; accordingly, the coastal district of Balasore has showed a relatively better resilience maintaining the ASI value at a higher level. This may is attributed to the irrigation water resources scenario providing more resilience to agriculture in the years of climatic induced natural disasters. Decline in cropped area and crop productivity due to climate change events is observed that is more in rainfed areas. Future efforts for climate smart agriculture need to be directed to less resilient districts.

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