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Vulnerability to climate change among the livestock rearers of eastern coastal region of India: A household level assessment

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ABSTRACT

The impact of global climatic change on agriculture as well as livestock has recently become a subject of increasing importance particularly in coastal ecosystem. The present study was designed to assess climate induced vulnerability at household level among the livestock rearers of eastern coastal region. Total 480 livestock rearers were randomly selected from the 4 coastal districts of 2 eastern coastal states of India as respondents. An exclusively "Social Vulnerability to Climate Change" index was developed by considering 40 indicators. The study revealed that average index score of vulnerability of livestock rearers of each studied districts as well as coastal states were negative with overall mean value -15.503±0.214. It was also found that livestock rearers of South 24 Parganas district were comparatively most vulnerable followed by Bhadrak, Ganjam, and Purba Medinipur districts. In overall, 41.667% of the livestock rearers were in medium vulnerability category followed by 35% and 23.333% in lower and higher vulnerability category, respectively.

Key words: Social vulnerability, Climate change, Livestock rearers, East coast of India

The higher growth in livestock sector has been observed during last 2 decades on account of market forces, technological change, increased availability of feed and fodders, investment in animal health, and development of marketing network for livestock products (Upadhyay 2010). The phenomenon of global climate change occurring due to GHG emissions has also been directly affecting the livestock production system world over. The adverse effect of excessive heat load (heat stress) on productive and reproductive performance include reduced feed intake, decreased general activity, increased selection of shade, lower growth and conception rates, increased respiratory and heart rates, panting activity, increased peripheral blood flow and sweating. These effects are well documented (Lal *et al.* 1987, Shinde *et al.* 1990, Kulkarni *et al.* 1998, Mandal *et al.* 2002, Tailor and Nagda 2005). The increase in thermal stress days due to temperature rise reportedly will cause an additional loss in milk production of 1.6 million tonnes in 2020 accounting about ₹2,365.8 crore at current price rate (Upadhyay *et al.* 2009).

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability to climate change as "*the degree to which a system is susceptible, or unable to cope with adverse effect of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.*" Exposure is the nature and degree to which a system is exposed to significant climatic variations. Sensitivity is the degree to which a system is affected, either adversely or beneficially by climate-related stimuli. Adaptive capacity is the ability of a system to adjust to climate change including climate variability and extremes, to moderate the potential damage from it, to take advantage of its opportunities, or to cope with its consequences (IPCC 2001). Two distinct notions of vulnerability are – bio-physical vulnerability and social vulnerability (Nyong *et al.* 2008). Bio-physical vulnerability is concerned with the ultimate impacts of a hazard event, and is often viewed in terms of the amount of damage experienced by a system as a result of an encounter with a hazard. Social vulnerability, on the other hand, is viewed more as a potential state of human societies that can affect the way they experience natural

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hazards (Vincent 2004, Adger 1999, Adger and Kelly 1999, Nyong *et al*. 2008). In most of the earlier studies vulnerability was assessed at regional level but not in household level. The vulnerability of crop farmers as well as fisherman was assessed. Therefore, it is conceptualize to assess livestock rearers' social vulnerability to climate change, as occurring at household level in the climate sensitive east coast of India.

MATERIALS AND METHODS

Sampling plan: Length of coastline of India including the coastlines of Andaman and Nicobar Islands in the Bay of Bengal and Lakshadweep Islands in the Arabian Sea is 7,517 km. Length of coastline of Indian mainland is 6,100 km and divided into east coast and west coast. East Coast is more vulnerable than the West Coast with respect to the frequency of occurrence of extreme climatic events (Patwardhan *et al.* 2003, Kumar and Tholkappian 2005). Therefore, present study was purposively conducted in east coast of India. Eastern Coastal region lies between Eastern Ghats and Bay of Bengal, stretching from Tamil Nadu in the south to West Bengal in the east. West Bengal, Odisha, Andhra Pradesh and Tamil Nadu are the 4 states in eastern coastal region of India. Among these Odisha and West Bengal were selected randomly. There were 6 districts, viz. Balasore, Bhadrak, Kendrapara, Jagatsighpur, Puri and Ganjam in coastal Odisha and South 24 Parganas, North 24 Parganas and Purba Medinipur in West Bengal. Ganjam and Bhadrak districts were selected randomly among 6 coastal districts of Odisha. From West Bengal, Purba Medinipur and South 24 Parganas were selected randomly. Thus, total 4 districts were selected randomly for the present study.

Blocks Rangeilunda, Ganjam, and Chhtrapur were selected randomly from the coastal blocks of Ganjam district of Odisha. Basudevpur, Tihidi, and Chandbali block were selected randomly from the coastal blocks of Bhadrak districts of Odisha. Deshapran (Contai-II), Ramnagar-I and Ramnagar-II blocks of Purba Medinipur district of West Bengal were selected randomly from its coastal blocks. In South 24 Parganas, blocks i.e. Gosaba, Basanti and Namkhana were selected randomly from its coastal blocks. Thus, the present study was confined in 12 blocks of 4 selected coastal districts.

A block-wise list of villages, where few numbers of livestock depended households were existing, were prepared in consultation with the block level veterinary officers. Subsequently, total 24 villages were selected randomly by selecting 2 villages from each selected block.

A livestock-rearer who has more than 30 years of experience in livestock rearing of at least one species among cattle, buffalo, goat, sheep and pig; and having main income from livestock was considered as respondents for the present study. Village-wise lists of livestock depended households were prepared with the help of livestock enumerator of that respective villages. Household head was considered as respondents for the present study. Subsequently, 20 respondents from each village were selected randomly. Thus, a total sample size of the present study was 480.

Piya *et al.* (2012) argued that vulnerability to climate change is multidimensional and is determined by a complex inter-relationship of multiple factors. They also argued that the first step in constructing the index comprises the selection of indicators, assigning of weights to these indicators, and finally these indicators are aggregated to form an index. Indicators and indices are useful in representing a complex reality into simpler terms. There are 2 approaches in the selection of indicators, data-driven and theory driven (Vincent 2004). But, each approach has its own limitations. Therefore, the best option is to verify the representativeness of the theory-based indicators with data availability from authentic sources. Judicial combination of both theory and data driven approaches was adopted while selecting the indicators used in this study.

Construction of social vulnerability to climate change (SVCC) index

i. Collection of the vulnerability indicators

Exposure: Historical changes in climatic variables like temperature and rainfall, occurrence and experience of extreme climate events were taken as indicators of exposure. In this study, it was assumed that effect of climatic variable was equivalent across the district. Therefore, district level data of different indicators of exposure were also considered as household level data for that particular district. Climatic indicators were calculated from the high resolution daily gridded temperature and rainfall data for the Indian region during the period of 30 years (1975 - 2004) developed by the India Metrological Department, Pune, India. Indicators used to measure exposure at the household level are presented in Box.1.

Box 1. Indicators to measure exposure at the household level (Refer Annexure – I for definition and details of each indicator)

1. Numbers of years having less number of rainy days than normal
2. Numbers of years having excess number rainy days than normal
3. Numbers of years having excess rainfall
4. Numbers of years having moderate metrological drought
5. Variation in rainfall
6. Numbers of days having very heavy rainfall
7. Numbers of days having extremely heavy rainfall
8. Numbers of heat wave incidences
9. Numbers of cold wave incidences
10. Change in mean temperature
11. Change in mean maximum temperature
12. Change in mean minimum temperature
13. Number of extreme climatic events experienced

Sensitivity: Sensitivity could best be measured by a change in income or livelihood attributed only to climatic

ANNEXURE - I

Numbers of years having less number of rainy days than normal	A day is called rainy day according to India Meteorological Department if the rainfall of that day is 2.5 mm or more. Frequency of such days were counted year-wise during 1975 to 2004 and compared with the normal number of rainy days. If it is found that percentage of rainy days are less than or equal to 80, then, it is considered that year has less number of rainy days.
Numbers of years having excess number rainy days than normal	A day is called rainy day according to India Meteorological Department if the rainfall of that day is 2.5 mm or more. Frequency of such days were counted year-wise during 1975 to 2004, and compared with the normal number of rainy days. If it is found that percentage of rainy days are greater than or equal to 120, then, it is considered that year has excess number of rainy days.
Numbers of years having excess rainfall	If the year-wise total rainfall of the district is greater than equal to 120% of normal rainfall. Then, it was considered that particular year has excess rainfall.
Numbers of years having moderate meteorological drought	If the year-wise total rainfall of the district is between 26 to 50% of normal rainfall. Then, it was considered that particular year is meteorological moderate drought.
Variation in rainfall	Coefficient of variation in year-wise rainfall during the period of 1975 to 2004.
Numbers of days having very heavy rainfall	A day is called very heavy rainfall day according to India Meteorological Department if the rainfall of that day is between 124.5 mm to 244.5 mm. Frequency of these days were counted during 1975 to 2004.
Numbers of days having extremely heavy rainfall	A day is called extremly heavy rainfall day according to India Meteorological Department if the rainfall of that day is more than 244.5 mm. Frequency of these days were counted during 1975 to 2004.
Numbers of heat wave incidences	A heat wave is defined if the maximum temperature at a grid point is 3°C or more than the normal temperature, consecutively for 3 days or more (Adopted from IMD, Pune).
Numbers of cold wave incidences	Cold wave is defined if the minimum temperature at a grid point is below the normal temperature by 3°C or more, consecutively for 3 days or more (Adopted from IMD, Pune).
Change in mean temperature	Deviation in daily mean temperature in the year 2004 from the base year 1975
Change in mean maximum temperature	Deviation in daily mean maximum temperature in the year 2004 from the base year 1975
Change in mean minimum temperature	Deviation in daily mean minimum temperature in the year 2004 from the base year 1975

factors. However, it was not possible to find this type of data. Instead, we were obliged to make the simple assumption that those areas with higher frequencies of climate extremes were subjected to higher sensitivity due to loss in yield and livelihood of rural masses (Deressa *et al.* 2008). A total 4 variables (Box. 2) were considered for calculating degree of sensitivity of the studied households.

Box 2. Indicators to measure sensitivity at the household level

1. Annual income from all sources
2. Proportion of income from livestock
3. Milk production
4. Subsistence ratio

Adaptive capacity: Adaptive capacity is conceptualized as the combined affect 5 types of livelihood assets, viz. physical, human, natural, financial and social. A total 23 variables/indicators were collated from the different published literatures and consultation with the subject matter specialist for calculating adaptive capacity of a household. Variables under each asset category are presented in Box.3.

Box 3. Indicators to measure adaptive capacity at the household level

Human asset

1. Age of the household head	2. Educational status of the household head
3. Family education status	4. Gender of the household head

Social asset

5. Social participation	6. Community participation
7. Community cohesiveness	8. Extension contact
9. Social migration	10. Number of relative in the village or community
11. Assistance from family members residing outside the village or community	12. Assistance from external agency
13. Farmer to farmer extension	

Physical and natural asset

14. Herd size	15. Modern farm equipment used
16. Sources of climatic information	17. Distance of the household from metal road
18. Distance to Purchase Critical Inputs	19. Distance to Sell Farm Output

Financial asset

20. Proportion of household expenditure to livestock	21. Productive animal in the herd
22. Availability of credit	23. Habit of savings

ii. *Selection of the appropriate indicators*

Having chosen the indicators, now these need to be normalized so as to bring the values of the indicators within the comparable range (Vincent 2004, Gbetibou and Ringler 2009, Feroze *et al.* 2010, Piya *et al.* 2012). Normalization is done by subtracting the minimum value from the observed value and dividing by range. Next step is the testing of suitability of indicators. Ravindranath *et al.* (2011) used principal component analysis (PCA) to identify the significant indicators and eliminate nonsignificant indicators.

After normalization, 3 factor analyses (one for each exposure, sensitivity and adaptive capacity) for each data set were run choosing principal component analysis for extraction and varimax method for rotation of the factors in SPSS 20. Indicators namely 'age', 'family education status', 'proportion of household expenditure to livestock', 'farmer to farmer extension', 'numbers of extreme climatic events experienced' and 'annual income from all sources' were dropped as their communality values were below the cut-off (0.50). Remaining data sets were used for further analysis i.e. assignment of weights to the indicators.

iii. *Assignment of weights to the indicators*

After selection of suitable indicators in item analysis, again PCA was run separately for each data set to obtain factor loading and eigen values. Kaiser normalization was used to identify the initial eigen values greater than 1. According to the number of eigen values greater than 1, the same number of components were extracted by using varimax rotational method for each indicator as shown in rotational component matrix. Then, method followed by Feroze *et al.* (2010) adopted for this study to assign the weights to the indicators.

iv. *Calculation of the vulnerability index*

The normalized indicators are then multiplied with the assigned weights to construct the indices separately for each component of vulnerability, viz. exposure, sensitivity and adaptive capacity separately. Finally, vulnerability index for each district and household is calculated as:

$$VI = AC - (E + S)$$

where, VI is the vulnerability index, AC is the adaptive capacity index, E is the exposure index, and S is the sensitivity index.

The overall vulnerability index facilitates inter-household comparison. Higher value of vulnerability index indicates lower vulnerability. Here, index value indicates the net effect of adaptive capacity, exposure and sensitivity. Negative value indicates that combined effect of exposure and sensitivity suppressed adaptive capacity. It may be considered as more vulnerable and as an alarming situation. This index does not give the absolute measurement of vulnerability; rather the index value highlighted a comparative judgement of among the studied districts and households.

vi. Differential level of vulnerability among the sampled households

All the sampled households were categorised into 3 differential level of vulnerability, viz. lower level of vulnerability, medium level of vulnerability and higher level of vulnerability on the basis of obtained score by the respective households. Cumulative square root frequency method was used to categories households into 3 categories.

RESULTS AND DISCUSSION

Vulnerability to climate change among the livestock rearers of coastal Odisha and West Bengal: The mean index value of components of adaptive capacity at household level in coastal region is given in Table 1. Duncun's multiple range test (DMRT) was applied for comparative evaluation of different asset categories of adaptive capacity at district level (Table 1). Livestock rearers from Bhadrak district had the highest mean value in human asset category than the other studied districts. It was found that human asset of Ganjam and Purba Medinipur districts did not differ significantly with each other. But, human asset of livestock rearers of Bhadrak, Ganjam/Purba Medinipur, and South 24 Parganas differed significantly ($P<0.05$) among themselves.

In social asset, livestock rearers of Ganjam district had the highest mean value. Table 1 also revealed that social asset of livestock rearers of Ganjam district differ

Table 1. Average score and comparative evaluation of different components of adaptive capacity (mean±SE)

Study area		Human asset	Social asset	Physical and natural asset	Economical asset
Odisha	Ganjam (n=120)	2.532±0.053[b] (3.425)	7.793±0.243 [a] (12.142)	4.838±0.170 [b] (7.422)	1.602±0.105 [b] (5.674)
	Bhadrak (n=120)	2.828±0.051[a] (3.425)	7.217±0.125 [b] (8.737)	4.116±0.115 [c] (5.829)	2.427±0.068 [a] (4.036)
	Odisha overall (n=240)	2.680±0.038 (3.840)	7.505±0.138 (12.142)	4.477±0.105 (7.422)	2.015±0.068 (5.674)
West Bengal	Purba Medinipur (n=120)	2.450±0.088[b] (3.840)	7.009±0.158 [b] (10.064)	4.529±0.115 [b] (6.185)	1.257±0.108 [c] (3.393)
	South 24 Parganas (n=120)	2.125±0.098[c] (3.840)	6.747±0.218 [b] (10.524)	5.583±0.137 [a] (6.837)	2.589±0.116 [a] (4.270)
	West Bengal Overall (n=240)	2.287±0.066 (3.840)	6.878±0.135 (10.862)	5.056±0.096 (7.535)	1.923±0.090 (4.446)
	Man Whitney U Statistics (Odisha Vs West Bengal)	25373* ($p = 0.019$)[#]	25741* ($p = 0.044$) [#]	21420** [#] ($p = 0.000$)	28428 ($p = 0.807$) [#]

Means at district level with different superscript in a column differ significantly at 5 % level significance, in a two tail test; multiple Comparisons are based on DMRT Post Hoc test;[#] Indicates ‘p’ value.**P= ≤0.01, in a two tiled test.*P = ≤0.05, in a two tailed test. Values in parenthesis indicate range.

significantly ($P<0.05$) with social asset of Bhadrak, Purba Medinipur and South 24 Parganas district. South 24 Parganas district of West Bengal had the highest mean value in physical and natural asset category as well as in financial asset category. Like human asset, there was no differentiation in physical and natural asset of livestock rearers of Ganjam and Purba Medinipur District. But, it was found a significant differentiation ($P<0.05$) among the livestock rearers of Bhadrak, Ganjam/Purba Medinipur, South 24 Parganas. In case of financial asset, there was no significant differentiation between the livestock rearers of South 24 Parganas and Bhadrak district. Whereas a significant differentiation ($P<0.05$) was found among the livestock rearers of Ganjam, Bhadrak/South 24 Parganas and Purba Medinipur district.

A particular community like *Gauda* community is engaged in livestock rearing in Ganjam district. But, in other 3 studied districts there is no particular community engaged in livestock rearing. This may be the reason of higher score of social asset among the livestock rearers of Ganjam district. A distinct authority i.e. the Sunderban Development Authority is working with a separate ministry at state government of West Bengal for the overall development of coastal South 24 Parganas district. This may be the reason of higher score in physical and natural asset as well as in financial asset.

Man Whitney U statistics was also used to delineate the differentiation, if any, of different assets of adaptive capacity at states level. It was found that there was a significant differentiation ($P<0.05$) between the livestock rearers of Odisha and West Bengal in both human asset and social asset. In physical and natural asset category, livestock rearers of coastal Odisha and West Bengal were found to differ significantly at 1% level of significance. But, there was no significant difference in financial asset between livestock rearers of coastal Odisha and West Bengal.

Mean values of vulnerability and its components are presented in Table 2. Livestock rearers from coastal South 24 Parganas had the highest adaptive capacity and livestock rearers of Purba Medinipur district had the lowest adaptive capacity (15.245±0.259). It was also found that there was no differentiation of adaptive capacity among the livestock rearers of Ganjam, Bhadrak and South 24 Parganas district. But, adaptive capacity of the livestock rearers of these districts differed significantly ($P<0.05$) with the livestock rearers of Purba Medinipur district. Like adaptive capacity, livestock rearers of South 24 Parganas district also had the highest exposure than the other studied districts. Exposure of livestock rearers of each studied district differed significantly ($P<0.05$) from each other. The study revealed that livestock rearers of Bhadrak district were most sensitive, whereas livestock rearers of Purba Medinipur district were least sensitive to climate change. Studied districts of Odisha i.e. Ganjam and Bhadrak did not differ significantly in terms of sensitivity of their livestock rearers. The same result was also found in the districts of West Bengal. But, interestingly, it was also revealed in the study that there was a significant differentiation between sensitivity of livestock rearers of Purba Medinipur district with Ganjam and Bhadrak district.

Here, vulnerability of each household was calculated by subtraction of sum of exposure and sensitivity was subtracted from the adaptive capacity. Mean vulnerability value of the livestock rearers of each districts as well as states were negative (Table 2). District with higher negative vulnerability value indicated that livestock rearers of that district are more vulnerable. Hence, livestock rearers of South 24 Parganas district were most vulnerable among

Table 2. Average value and comparative evaluation of vulnerability and its different components in coastal region (mean±SE)

Study area		Adaptive capacity	Exposure	Sensitivity	Vulnerability
Odisha	Ganjam (n=120)	16.765±0.401[a] (17.029)	28.245 [c]	1.426±0.015[ac] (1.594)	–12.939±0.397[c] (16.465)
	Bhadrak (n=120)	16.588±0.214[a] (12.363)	31.267 [b]	1.504±0.032[a] (1.711)	–16.183±0.209[b] (12.587)
	Odisha overall (n=240)	16.676±0.227 (17.744)	29.756±0.098 (3.022)	1.481±0.022 (1.711)	–14.561±0.247 (20.403)
West Bengal	Purba Medinipur (n=120)	15.245±0.259[b] (0.256)	26.137 [d]	1.364±0.025[b] (1.337)	–12.256±0.259[c] (16.419)
	South 24 Parganas (n=120)	17.045±0.309[a] (17.744)	36.300 [a]	1.378±0.027[bc] (1.337)	–20.633±0.312[a] (17.536)
	West Bengal Overall (n=240)	16.145±0.208 (20.638)	31.219±0.329 (10.162)	1.371±0.018 (1.378)	–16.445±0.338 (23.679)
Man Whitney U Statistics (Odisha Vs West Bengal)		28187 (p = 0.687)[#]	–4.264** (t-test) (p = .000) [#]	22800** (p = 0.000) [#]	24360** (p = 0.003) [#]

Means at district level with different superscript in a column differ significantly at 5 % level significance, in a 2 tail test. Multiple comparisons are based on DMRT Post Hoc test. [#] Indicates 'P' value. **P=≤0.01, in a 2-tailed test.Values in parenthesis indicate range.

Table 3. Distribution of households of coastal region according to differential level of vulnerability

Study area		Low (–13.771 to –2.979) [#]	Medium (–18.332 to – 13.772) [#]	High (–29.786 to –18.333) [#]
Odisha	Ganjam (n=120)	50 (41.667)	69 (57.500)	1 (0.833)
	Bhadrak (n=120)	20 (16.667)	82 (68.333)	18 (15.000)
	Odisha overall (n=240)	70 (29.167)	151 (62.917)	19 (7.916)
West Bengal	Purba Medinipur (n=120)	96 (80.000)	19 (15.833)	5 (4.167)
	South 24 Parganas (n=120)	2 (1.667)	30 (25.000)	88 (73.333)
	West Bengal Overall (n=240)	98 (40.833)	49 (20.417)	93 (38.750)

[#] Indicate score of categorisation (remaining), values in parenthesis indicate percentage.

the studied districts. Livestock rearers of South 24 Parganas district had the highest adaptive capacity and in the same time they also possessed highest exposure. This may be the reason of higher vulnerability of livestock rearers of South 24 Parganas. Vulnerability, exposure and sensitivity of the livestock rearers of coastal Odisha was also significantly different from their counter parts of West Bengal. Piya *et al.* (2012) analysed the micro-level vulnerability of rural *Chepang* community in Nepal and reported that poor households with low adaptive capacity are vulnerable anywhere, irrespective of where they are located. Ashoke and Sasikala (2012) studied farmers' vulnerability to rainfall variability in Pudukkottai district of Tamil Nadu through livelihood vulnerability index-IPCC approach and highlighted the marginally higher vulnerability of the households in below normal rainfall blocks.

Differential level of vulnerability among the livestock rearers of coastal region

Majority of the livestock rearers of coastal Odisha as well as its district were in medium vulnerability category (Table 3). Whereas 80% of the livestock rearers of coastal Purba Medinipur district of West Bengal were in lower vulnerability category. But, majority of the livestock rearers of South 24 Parganas district of West Bengal were in higher vulnerability category. Nyong *et al.* (2008) reported that 42% household in the Sahelian zone of Northern Nigeria were classified as highly vulnerable, 33% as vulnerable and 25% as less vulnerable. Deressa *et al.* (2008) analysed the vulnerability of Ethiopian farmers at household level and it was found that almost all the surveyed farmers were in below poverty line and their socio-economic scenario will be more severe in future.

Though livestock rearers of Purba Medinipur district had the lowest adaptive capacity, but, they also were having lowest exposure as well as sensitivity to climate change. This may be the reason of comparatively lower vulnerability of livestock rearers of Purba Medinipur district. On the other hand, due to the highest exposure to climatic variable to the coastal South 24 Parganas combined with comparatively higher sensitivity, majority of the livestock rearers of South 24 Parganas were in higher vulnerability category.

This finding clearly indicated that combined effect of exposure and sensitivity suppress over the adaptive capacity of the livestock rearers of coastal region and this situation may be considered as an alarming situation. Inter districts comparison clearly showed that livestock rearers from South 24 Parganas had the highest adaptive capacity. But on the contrary, they were most vulnerable due to their highest exposure to climatic variable. However, biophysical elements determining the exposure like temperature, rainfall and natural disasters are beyond the immediate influence of the policy makers. Out of the 3 components of vulnerability, adaptive capacity is the component having direct policy implications. Improving the adaptive capacity also has indirect implications on reducing the sensitivity of the livestock rearers and finally the reduced vulnerability.

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