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Climate Change Impact and Sustainable Adaptation Strategies for Climate-Resilient Paddy Cultivation in Chandrapur District, Central India

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Abstract

Agriculture is the principal sector of the Indian economy. Rice paddies are a temperature-sensitive crop and require a sufficient quantity of water for cultivation. The study's objective is to observe, assess, and develop adaption techniques for farmers who are marginalized in Chandrapur district, central India, through the practice of paddy cultivation. For this purpose, 70 marginalized farmers were identified from the eight villages of the district. The information from this group of farmers was gathered using a custom-created, and field-tested questionnaire. The major climate change impact on various paddy growth stages and livestock were identified as soil fertility reduced (94.28%), high temperature reduced paddy growth (88.56%), predominance of insects and pests increased to 98.57%, and new pest and bug species are impacting paddy (86.14%), paddy quality deteriorated at the time of harvest (92.85%), heatstroke in livestock engaged in paddy cultivation (100%) etc. To increase this group of marginalized farmers' capacity for resilience, climate-smart agriculture strategies for various paddy growth stages have been identified from the scientific and technical literature and discussed in this document. These strategies include village seed bank, dryland zero tillage, modified rice intensification system and rice drum seeding, community paddy nursery, use of composite varieties, micro dams, irrigation scheduling, paddy-fish agriculture system, designing of free stall barn etc. In addition to these strategies, other support mechanisms such as national-level policy, financial provision, institutional mechanism, capacity development and improvement will transform from subsistence farming to sustainable farming and lead to sustainable livelihood.

Keywords: adaptation; agriculture; Chandrapur, climate change; climate-smart agriculture; marginalized farmer; paddy

Introduction

Regional climate fluctuations are becoming more pronounced, which is posing problems for agricultural productivity. Food security has also been threatened by numerous factors and is expected to face more uncertainties in the future. According to projections made in 2015 by the Global Forum for Food and Agriculture, there will be two billion more people on the planet in 2050, and food demand will rise by 60–90%. Global consensus has already agreed upon the climate aspects' crucial role in agriculture [1,2], specifically in the production of grain. Grain has proven to be the most vital sector for meeting the food demand of a population of over six billion all over the planet [3]. More than 3 billion people worldwide consume rice, making it the most widely consumed meal on the planet. More people are fed by rice than by any other crop [4]. Asian countries are the most dominant producers and consumers of rice, where ninety percent of the world's rice is produced, [5]. A further increase in rice production is required to meet the increasing demand caused by the population increase and economic development. India is the world's second-largest producer of rice after China, where rice is cultivated on 43.78 million hectares (ha) to produce 118.43 million tonnes of rice, with a yield of around 2705 kg/ha [6].

Consumed in nearly every Indian state, rice is also a staple food. It grows in a variety of soil types and climates. India's production level in the rice crop is low when compared to many other countries worldwide, and the predicted yield has been decreasing as a result of climate change [7]. Additionally, marginal (landholding < 1.0 hectares, or ≤ 2.5 acres), small and medium farmers own roughly 90% of India's cultivated land, which is another barrier to raising the nation's rice yield [6]. Variability due to climate change is likely to deteriorate the issue of future food security by creating pressure on agriculture and disturbing its sustainability [8]. India's farming population has small landholdings, limited financial resources, and inadequate institutions, infrastructure, and technologies to withstand the shocks caused by climate change [9]. The number of rainy days and rainfall variability will have a primary impact on rainfed agriculture [10]. Furthermore, farmers' suicide during the last two decades (2000-2020) has also emerged as one of the major problems. During 1997 and 2005 in India, one farmer committed suicide every 32 minutes. The suicide trend is in the order of marginal farmers (50.3%) > small (25.9%) > large farmers (7.9%) [11]. The impact of climate change on small, disadvantaged farmers that cultivate rice, as well as sustainable adaptation techniques to mitigate these effects are not documented in the literature. Therefore, the purpose of this study was to close this identified knowledge gap by evaluating the effects of climate change on disadvantaged farmers who cultivate rice and developing sustainable adaptation plans for paddy agriculture that is climate resilient. The new knowledge added in this subject domain will enhance the opportunities available to lead to a new path for sustainable agriculture.

Study area

The Chandrapur district (19o25' N to 20o45' N and 78o50' E to 80o10' E) is located in central India and lies in the Eastern part of the state of Maharashtra (Figure 1). The district's climate is defined by a scorching summer (47oC) and year-round dryness, with the post-monsoon season occurring in October and November. The area receives 1142 mm of precipitation on average per year. The soil profile is medium to deep red and black soil with lime mix, and yellow soil. Out of the net sown area of the district 4,51,500 ha, rice paddies are cultivated across 1,82,000 ha (2013-14) and 1,61,000 ha (2014-15) with an average yield of 1,111 kg/ha. Of the total cultivators, small /marginalized farmers contribute 1,420,000 tones? (64.5%).

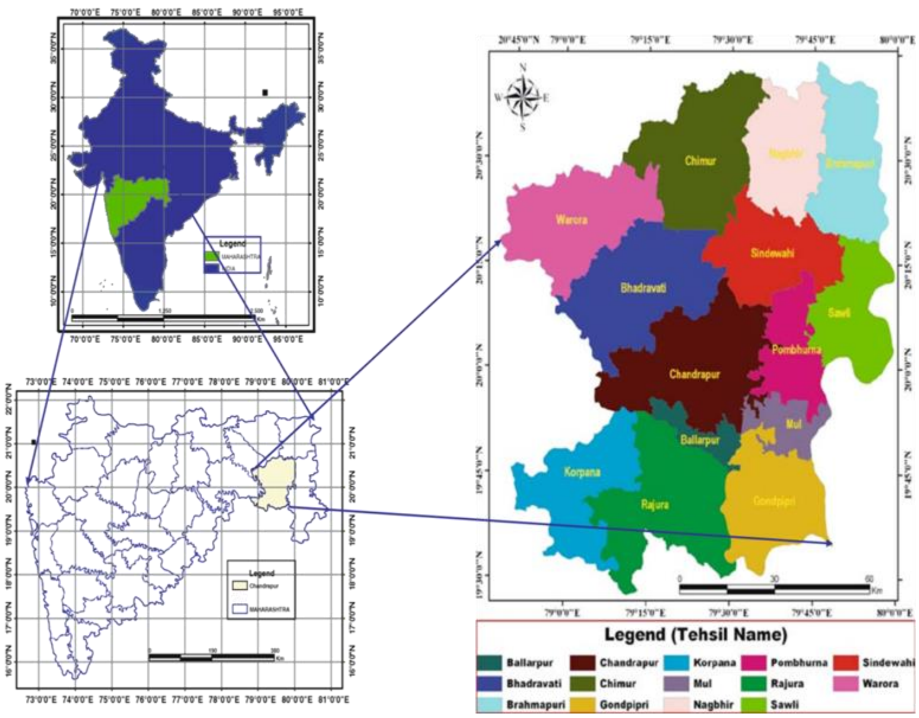

Figure 1. Administrative blocks in the Chandrapur district [12]

Methodology

Eight villages in the Chandrapur district, where rice is the primary crop, were chosen for the study to evaluate the effects of climate change on marginalized farmers and the need for sustainable adaptation measures. The study area includes villages Mamla, Nimbada, Borda, Ghanta Chowki, Pimpalkhuta, Ajaypur, and Lohara. The sample population of farmers for this study (n=70) was collected by employing a purposive sampling methodology. Farmers with agricultural land sizes of less than 1.0 hectares (2.5 acres) and those who have been engaged in agriculture for less than 15 years met the criteria for selection of the sample population. A quantitative technique was employed for primary data collection. A carefully created, produced, and field-tested questionnaire was employed for this purpose. The Likert scale was utilized to provide quantitative and comparable data for the responses. SPSS (Statistical Package for the Social Sciences) and Origin-pro were employed to analyze the data that had been gathered. The secondary data were acquired from official government sources such as the India Meteorological Department, Chandrapur's Agriculture Science Centre, and the Census of India. The sustainable adaptation strategies for climate-resilient paddy cultivation were identified from the published literature which includes research papers, scientific and technical reports, case studies etc. Furthermore, these adaptation strategies have been segregated based on paddy growth stages. Moreover, to reduce the climate change-induced impact on livestock, suitable measures were also identified. Colibacteriosis is an acute infectious disease that manifests itself in a newborn baby animal’s first days after birth. Symptoms include diarrhea, internal intoxication, dehydration, hemoptysis, and neurological symptoms. Intestinal coliforms are transmitted through the gastrointestinal tract and respiratory tract of healthy animals, through contaminated equipment and feed processing. Infected young animals usually die within 4-12 hours. In veterinary medicine, certain groups of antibiotics such as tetracycline, chloramphenicol, neomycin, and polymyxin are used to treat infectious diseases [7]. However, the selection of antibiotics based on the determination of their susceptibility has become a significant issue in today's problem of microbial resistance. Our study aimed to identify and isolate *Escherichia coli (E. coli)* and *Salmonella spp* from pathological material and swabs. Additionally, we conducted antimicrobial susceptibility testing on the isolated strains.

Results and Discussion

The data collected through the questionnaire were assessed per the percentage of responses and ranked according to the descending order.

Table 1 shows the effects of climate change on paddies during sowing, crop growth, harvest, and livestock reared by this group of farmers.

The soil fertility reduction (94.28%) is the major impact reported during sowing followed by paddy growth reduction (88.56%), irrigation water scarcity (88.57%), and more rounds of sowing due to seed loss (71.42%). Regarding agricultural growth, there have been reports of increased insect/pest prevalence (98.57%) and insects pests that are new to the rice paddies (86.14%).

During harvesting, late harvesting affects the paddy quality (92.85%) followed by affecting ready-to-harvest paddy (78.57%). In the case of livestock, scarcity of drinking water percentage? heatstroke (100%), and fodder production reduction (88.23%) have been identified as major impacts.

Other additional climate change impacts on paddy fields includes hail storm damage to paddy crops, discoloration of the paddy spikelet’s due to uneven rainfall during harvesting, an increase in the cost and demand of seeds, more pesticides/insecticides utilization increased due to insect/pests becoming more resistant due to climate change, gusty winds result into lodging of paddy crop, increasing weed growth disturbs the growth of paddy, etc.

From the findings obtained in this study, it can be stated that marginalized farmers' way of looking at and understanding climate change is very clear, and many other studies report similar results.

The results corroborate with Mertz et al., [13], Banerjee [14], Panda and Singh [15], Putriawanti and Asai [16], Rahman and Alam [17], Somboonsuke et al., [18], Jamshidi et al., [19].

Table 1

Climate change impact on paddy (Values in parenthesis are in percentage)

Sowing
Soil fertility reduced (94.28)
High temperature reduces paddy growth (88.56)
Irrigation water scarcity (88.57)
Low rainfall (84.28)
More rounds of sowing due to seed loss (71.42)
Late/no seed germination (67.14)
Crop growth
Insect/pests attack increased (98.57)
Insect species that are new to paddy (86.14)
Reduction in crop productivity (82.85)
Poor quality of yield (78.57)
Stunted growth (61.42)
More weed growth affecting crops (45.71)
Harvest
Quality deteriorated (92.85)
Climate change affecting ready harvest paddy (78.57)
Climate disasters destroy paddy partially/completely (74.28)
Per acre paddy yield in last five years decreased (71.42)
Livestock
Scarcity of drinking water (100)
Heatstroke (100)
Fodder production reduced (85.28)
Vector-borne diseases increased (61.76)

Material and methods

Crop residue burning (94.28%) has been perceived as the agricultural activity responsible for climate change by this group of marginalized farmers. It is reported that climate change is due to the cutting down of trees and pollution. Few respondents thought climate change is due to global warming [14]. It is found that smallholder farmers have acclaimed this phenomenon to be caused by human activity [19]. It is reported that climate change has a direct effect on paddy growth in Japan [20]. The study reported that there was an increase in dieback and mortality of seedlings, pests, and diseases [17]. This result is in agreement with the observation obtained from the Indian villages' study area. Late or no seed germination is one of the major climate change impacts on paddy fields (67.14%), along with an increased prevalence of insect/pest (98.57%) and insect species that are new to paddy (86.14%) identified from the study area. Reduction in surface water quantity is reported by farmers from the study area. This observation was also reported by Banerjee [14]. Enhanced insect/pest attack observations are in agreement with Harvey et al., [21] and Banerjee [14]. The findings of this study are consistent with the rise in crop and animal diseases noted by Panda and Singh [15].

Agricultural adaptation strategies to be used by farmers include a change in cropping patterns, adaptation to rainfed crops, and restoration of traditional rainwater harvesting techniques, which are also reported by Akinnagbe and Irohibe [22]. Selling household assets is one of the coping measures reported by Aniah et al., [23] which is also reported from the study area. Farmers also raise money for agricultural activities by mortgaging wives' jeweler (yes 37.14% and sometimes 38.57%).

Sustainable adaptation strategies for paddy cultivation

Strategies for sustainable adaptation include those that reduce or eliminate greenhouse gas emissions in addition to adapting and strengthening system resilience [24],. Sustainable adaptation strategies for the observed climate change impact on paddy cultivation are identified from the scientific and technical literature and are presented in Table 2.

Table 2

Sustainable adaptation strategies for paddy

Sowing	
Rice husk as a biochar fertilizer	
Precision agriculture	
Dryland zero tillage	
More rounds of seed due to seed loss	
Change paddy planting dates	
Village-level seed bank	
Seed hardening	
Seed coating and scarification	
Irrigation	
Change up the wet and dry times	
Rubber check dams	
Modified rice intensification system	
Mulching	
Insect pest	
Intercropping	
Polyculture	
Trap cropping	
Companion planting	
Productivity reduced	
Conservation agriculture	
System of rice intensification	
Paddy-fish agriculture system	
Crop diversification	
Heatstroke in livestock	
Design free-stall barns	
Evaporating air pads	
Combined intermittent wetting and forced ventilation	
Fodder production reduced	
Development of feed bank in rangeland during other season	
Acacia colei tree used as a fodder	
Rotational grazing	
Fodder substitution	

Village seed bank

One of the most essential strategies for instilling resilience against climatic variability is to provide farmers with enhanced and stress-tolerant seeds at the right time. A village seed bank provides an emergency seed source for farmers who need paddy resowing due to a lack of seeds. By enhancing seed security, seed banks make sure that an adequate supply of the correct kinds of seed is accessible at the right time and for a fair price [25].

Dryland zero tillage

Zero tillage on dry land is the most effective way to reduce carbon dioxide emissions. Benefits of zero- or no-tillage and soil conservation include increased yields, decreased production costs, and decreased erosion and land degradation. In the no-till and direct seeding methods, there is little or no soil disturbance, which is sometimes combined with residue retention, crop rotation, and the use of cover crops to maintain or improve natural soil fertility. This approach also frequently employs direct seed broadcasting [26].Non-puddled direct-seeded paddy is a method of planting paddies that avoids repetitive puddling by drilling dry seeds into the soil. In some nations, there has been a change from traditional transplanting to direct seeding in recent years,

Modified system of rice intensification (MSRI)

Paddy seedlings are raised separately on a mat nursery with MSRI. With a few exceptions, this strategy is very similar to the rice intensification system. Seedlings are transplanted with a machine transplanter in MSRI, and irrigation water is applied in alternate wetting and drying. When compared to standard paddies, MSRI uses a spacing of 25 x 16 cm, and water application can be reduced by about 16 percent In MSRI, land levelling is necessary to maintain a thin layer of water during the transplantation process..

MSRI can reduce seedling mortality by 50%, enhance tillering, boost panicle quantity, and reduce pest and disease incidence [28, 29].

Drum seeding of rice

The drum seeding technique is used for the direct sowing of pre-germinated paddy seeds in fiber drums which is used to disperse seeds evenly in puddled and levelled fields. For this purpose, overnight water-soaked and sprouted paddy seeds of approximately 35 to 40 kg per hectare are used. These sprouted seeds are then air-dried for 30 minutes in the shade for smooth administration with the help of drum seeders. To keep the soil moist, the excess water in the field is drained down. For the initial 2-3 days, irrigation activity is avoided to enable roots and soil anchoring. The water level in the field can rise as the seedlings grow, allowing for improved weed control. Because of the line planting and early maturity of the crop, this practice can assist in saving seed, water, and labor while also increasing yield (by 7-10 days). Drum seeding lowers cultivation costs by eliminating the need for paddy nursery production and subsequent transplantation [30].

Community paddy nursery

The community paddy nursery strategy entails planting in a hamlet with guaranteed irrigation every two weeks. If the monsoon gets delayed by two weeks, this emergency nursery will be developed by 15 June. It will have a long-duration paddy variety (>140 days) with 2-4 weeks old age that can be transplanted in the first fortnight of July. The first week of July sees the planting of a second nursery with medium-duration kinds (125–135 days) in case the monsoon is postponed by an additional month. In case of additional postponement or drought-like circumstances, the third nursery is established by the middle of July [30].

Use of composite paddy varieties

The advantage of composite paddy varieties is that they are more resistant to climate stress. They are far superior to the local cultivars, which yield higher returns and have a slightly longer cycle (4 months at least). Farmers can use drought-tolerant crops or enhanced cultivars with a small growing cycle (3 months) that are less susceptible to changing weather conditions. These are hybrids and, in particular, composites that can withstand extreme dehydration [31].

Change paddy planting dates

The paddy’s development and output depend on the planting date. The objective is to determine the optimal date for paddy establishment to allow the reproductive and grain-filling stages of the crop to occur during the colder months when temperatures vary.

Alteration of farm management practices

To deal with precipitation uncertainty, farmers in various nations divided their paddy plots into two halves and used various management techniques. While the second half of the plot is planted using a drought-resistant, less water-intensive "system of rice intensification" cultivation technique, the first half of the plot is grown using traditional wet-paddy techniques, which can endure significant rains [32].

Micro dams

By building small dams to retain water, farmers may create a hydro agricultural technology that can postpone a drought by a few days, increasing paddy harvests [33]. A flexible rubber check dam can be used for stream flow regulation, flood control, and water conservation. When inflated, this flexible dam can act as a check dam, and when deflated, it can be used for flood mitigation and flushing of sediment. Rubber dams in watersheds have enhanced paddy output and productivity, allowing farmers to plant another crop, hence increasing cropping intensity and net profit [34].

Irrigation scheduling

When a sophisticated irrigation scheduling technique is utilized, significant water savings can be realized without affecting yields. Alternate wetting and drying is a water-saving system that uses irrigation water more efficiently. Emissions from paddy fields can be reduced by adopting intermittent irrigation. Transferring and adopting a paddy-integrated crop management method would boost nitrogen fertilizer efficiency and lower nitrous oxide emissions.

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Leaf color chart technique

The leaf color chart (LCC) is a four-panel that correlates to the actual colors of paddy leaves and was developed for paddy production in Asia. The LCC is made up of plastic panels in a variety of green colors, varying from yellowish-green to dark green. Farmers may use LCCs in the field to identify how much nitrogen fertilizer they need to utilize efficiently and maximize paddy harvests. It can be used to reduce greenhouse gas emissions by managing nitrogen in real-time and synchronizing nitrogen application with crop demand [37].

Urea deep placement (UDP)

The deep fertilizer placement has been identified as a way to improve fertilizer efficiency. Shortly after the paddy is transplanted, urea granules (1–3 g) are placed at 7–10 cm soil depth. UDP doubles the percentage of nitrogen received by the paddies, thus lowering nitrogen loss in the air and surface water runoff. This has resulted in an average yield gain of 18% in farmers' fields. The UDP method pushed paddy production by 900–1100 kg/ha while reducing urea use by 78–150 kg/ha [38, 39].

Paddy-fish agriculture system

The paddy-fish agricultural technique uses stream water to irrigate rice fields, which are home to swimming fish. As a result, an ecological symbiosis is established. Fish eat weeds and larvae, supply nutrients and fertilizer to the paddy, and control the microclimate. This technique lowers the manpower costs involved in applying fertilizer and controlling pests. Fish activities provide a disturbance that keeps the water's oxygen levels high, which is necessary for fish development. This strategy creates advantageous circumstances that support the preservation of additional crop species [40].

Cropping system to short growing seasons and staggering planting

Adapting cropping systems to shorter growing seasons, and switching crops to those productive at higher water and temperature stresses are important to mitigate climate change-induced impact. A staggered planting technique can be used to deal with dry spells. The loss of seed capital is decreased by the practice of extending the seedlings through time and leaving gaps in the landscape. This ensures that natural dangers do not constantly hinder production and that certain areas benefit from more moderate precipitation conditions.

In-situ incorporation of biomass and crop residues

After harvesting Kharif crops, a rotavator can aid with early seedbed preparation for rabi crop sowing. This saves energy during the tillage process and thoroughly mixes and absorbs the previous crop's stubbles into the soil. This enhances the physical qualities of the soil, which leads to higher crop production. Crops such as daincha and cowpea can be used in damp situations to boost soil health [30].

Designing free-stall barns

Creating free-stall barns with a maximum amount of natural ventilation throughout the summer would lessen the negative effects of heat stress on cattle used in paddy cultivation. The use of wide spaces, proper height of sidewalls and roof ridges, and an absence of natural features and structures all help to improve natural airflow. Ample ventilation is required to maintain air quality throughout the winter while also providing essential protection from cold stress [41].

Evaporating air pads

Evaporative cooling can be utilized to cool the air surrounding the cows used in paddy farming. To cool the air around the cattle, techniques including cross-ventilation, tunnels with high-pressure misters and evaporating pods with fans and high-pressure sprayers can be utilized. This approach holds promise for dry, arid regions. The ambient temperature drops and the humidity rises as a result of the vaporization of water [42].

Conclusions

The number of climate change impacts on paddy are observed in its various growth stages. Owing to limited access to finance, infrastructure, institutions, and technologies enhances the marginalized farmers' vulnerability to climate change. To have climate-resilient agriculture, this group of farmers needs to transform their way of paddy cultivation by adopting sustainable agriculture strategies, which will pave the way for sustainable agriculture. Moreover, the path forward towards climate-resilient agriculture needs a dynamic approach so that these adaptation strategies will work. This approach will involve mainstreaming climate-resilient agriculture into national policies and programs, priority and constraint analysis in its implementation, diversification in adaptation, time-bound goals and targets, enhancement of implementation capacity, financing, institutional arrangement, and safety nets. Furthermore, because these farmers have low levels of education, nonprofit groups and the Agriculture Science Centre should work together to raise knowledge of these sustainable adaptation options among them in their native languages. These identified adaptation strategies for effective implementation need to be prioritized based on time scales determined as immediate (<1 year), over a while (1-3 years), and long-term (4-5 years). The adaptation of these sustainable agriculture strategies for climate-resilient paddy cultivation will transform subsistence farming into sustainable farming and liberate this group of marginalized farmers from the vicious cycle of poverty, climate change-induced crop failure, debate, and suicide, and ultimately pave the way for sustainable livelihood.

References

[1] Wang J., Mendelsohn R., Dinar A., Huang J., Rozelle S. and Zhang L. (2009) The impact of climate change on China's agriculture. Agric. Econ. 40, 323-337. https://doi.org/10.1111/j.1574-0862.2009.00379.x

[2] Yang X.G., Liu Z.J. and Chen F. (2011) The possible effects of global warming on cropping systems in China VI-Possible effects of future climate change on northern limits of cropping system in China. Sci. Agric. Sin. 44, 1562-1570.

[3] Li W., Tang H.J., Qin Z.H., You F., Wang X.F., Chen C.L., Liu X.M. (2014) Climate change impact and its contribution share to paddy rice production in Jiangxi, China. J. Integr. Agric.13(7), 1565-1574. https://doi.org/10.1016/S2095-3119(14)60811-X

[4] Maclean J.L., Dawe D., Hardy B. and Hettel G.P. (Eds.), ''Rice Almanac,'' p. 253. International Rice Research Institute, Los Banos, Philippines.Wassmann R., Jagadish S.V.K., Sumfleth K., Pathak S., Howell G., Ismail A., Heuer S. (2009) Regional vulnerability of climate change impacts on Asian rice production and scope for adaptation. Adv. Agron. 102, 91-133. https://doi.org/10.1016/S0065-2113(09)01003-7

[5] Agricultural Statistics at a Glance. (2020). Government of India Ministry of Agriculture & Farmers Welfare Department of Agriculture, Cooperation & Farmers Welfare Directorate of Economics and Statistics.

[6] Palanisami K. (2017). Climate Change and India's Future Rice Production: Evidence from 13 Major Rice Growing States of India. SF J Glob. Warm. 1, 2. https://doi.org/10.23959/sfjgw-1000010

[7] Gupta A. and Pathak H. (2016) Climate Change and Agriculture in India. A Thematic Report of National Mission on Strategic Knowledge for Climate Change (NMSKCC) under National Action Plan on Climate Change (NAPCC).

[8] Shirsath P.B., Aggarwal P.K., Thornton P.K. and Dunnett A. (2017) Prioritizing climate-smart agricultural land use options at a regional scale. Agric. Syst. 151, 174-183

https://doi.org/10.1016/j.agsy.2016.09.018

[10] Venkateswarlu B. and Shanker A.K. (2012) Dryland agriculture: Bringing resilience to crop production under changing climate. In: Crop Stress and its Management: Perspectives and Strategies. B. Venkateswarlu, A. Shanker, C. Shanker & M. Maheswari, (eds). Springer, Dordrecht, The Netherlands, 19-44. https://doi.org/10.1007/978-94-007-2220-0_2

[11] Manjunatha A.V. and Ramappa K.B. (2017) Farmer suicides: An All-India Study, Agriculture Development and Rural Transformation Centre Report, Institute for Social and Economic Change, Karnataka, India.

[12] Satapathy D.R., Salve P.R. and Katpatal Y.B. (2009) Spatial distribution of metals in ground/surface waters in the Chandrapur district (Central India) and their plausible sources. Environ. Geol. 56(7), 1323-1352. https://doi.org/10.1007/s00254-008-1230-3

[13] Mertz O., Mbow C., Reemberg A. and Diouf A. (2009) Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. Environ. Manag. 43, 804-816. https://doi.org/10.1007/s00267-008-9197-0

[14] Banerjee R.R. (2015) Farmer's perception of climate change, impact, and adaptation strategies: A case study of four villages in the semi-arid regions of India. Nat. Hazards. 75, 2829-2845. https://doi.org/10.1007/s11069-014-1466-z

[15] Panda C.K. and Singh S.R. (2016) Marginal and small farmers' climate change adaptation perception and adaptation. Int. J. Agric. Environ. Biotechnol. 9(5), 839-846. https://doi.org/10.5958/2230-732X.2016.00108.X

[16] Putriawanti and Asai K. (2016) Questionnaire Survey on farming adaptation for climate variability in Serang municipality, Indonesia. Mem Fac Eng Yamag-Uchi Univ, 67(2): 59-66.

[17] Rahman M.H. and Alam K. (2016) Forest Dependent Indigenous Communities' Perception and Adaptation to Climate Change through Local Knowledge in the Protected Area- A Bangladesh Case Study. Clim. 4, 12. https://doi.org/10.3390/cli4010012

[18] Somboonsuke B., Phitthayaphinant P., Sdoodee S. and Kongmanee C. (2018) Farmers' perceptions of impacts of climate variability on agriculture and adaptation strategies in Songkhla. Kasetsart J. Soc. Sci. 39(2), 277-283. https://doi.org/10.1016/j.kjss.2018.05.006

[19] Jamshidi O., Asadi A., Kalantari K., Azadi H. and Scheffran J. (2019) Vulnerability to climate change of smallholder farmers in the Hamadan province, Iran. Clim Risk Manag. 23, 146-159. https://doi.org/10.1016/j.crm.2018.06.002

[20] Watanabe T. and Kume T. (2009) A general adaptation strategy for climate change impacts on paddy cultivation: special reference to the Japanese context. Paddy Water Environ. 7, 313-320. https://doi.org/10.1007/s10333-009-0179-5

[21] Harvey C..A., Rakotobe Z.L., Rao N.S., Dave R, Razafimahatratra H., Rabarijohn R.H., Rajaofara H. and MacKinnon J.L. (2014) Extreme vulnerability of smallholder farmers to agricultural risks and climate change in Madagascar. Philos. Trans. R. Soc. B. 369, 20130089. https://doi.org/10.1098/rstb.2013.0089

[22] Akinnagbe O.M. and Irohibe I.J. (2014) Agricultural adaptation strategies to climate change impacts in Africa: A review. Bangladesh J. Agric. Res. 39(3), 407-418. https://doi.org/10.3329/bjar.v39i3.21984

[23] Aniah P., Kaunza-Nu-Dem M.K. and Ayembilla J.A. (2019) Smallholder farmers' livelihood adaptation to climate variability and ecological changes in the savanna agro ecological zone of Ghana. Heliyon. 5(4), e01492. https://doi.org/10.1016/j.heliyon.2019.e01492

[24] FAO. (2013) Climate-Smart Agriculture Sourcebook. Food and Agriculture Organization. United Nations. http://www.fao.org/3/i3325e/i3325e.pdf.

[25] Boef D.W.S., Dempewolf H., Byakweli J.M. and Engels J.M.M. (2010) Integrating genetic resource conservation and sustainable development into strategies to increase the robustness of seed systems. Agroecol. Sustain. Food Syst. 34, 504-531. https://doi.org/10.1080/10440046.2010.484689

[26] Rosegrant M.W., Jawoo K., Cenacchi N., Ringler C., Robertson R., Fisher M., Cox C., Garrett K., Perez N.D. and Sabbagh P. (2014) Food security in a world of natural resource scarcity: the role of agricultural technologies. IFPRI (International Food Policy Research Institute), Washington, USA

[27] Stoop W.A., Adam A. and Kassam A. (2009) Comparing rice production systems: A challenge for agronomic research and for the dissemination of knowledge-intensive farming practices. Agric. Water Manag. 96, 1491-1501. https://doi.org/10.1016/j.agwat.2009.06.022

[28] Gurava R.K., Kakumanu K.R., Tirapamma S., Palanisami K. and Nagothu U.S. (2013) Partnership as key for enhancing technology transfer: A case of direct sowing rice in Guntur district, Andhra Pradesh, India. Compendium: National Seminar on Futuristic Agricultural Extension for Livelihood Improvement and Sustainable Development. January 19-21. Rajendranagar, Hyderabad, India.

[29] Prasad Y.G., Maheswari M., Dixit S., Srinivasarao C., Sikka A.K., Venkateswarlu B. . . Mishra A. (2014) Smart Practices and Technologies for Climate Resilient Agriculture. Central Research Institute for Dryland Agriculture (ICAR), Hyderabad. 76 p.

[30] Feumba R.A., Yongsi H.B., Christopher R.B., Chétima B. and Cyrille T.T. (2016) Adaptations of the Agricultural Calendar and Agricultural Techniques to Climate Change in the Highlands of Cameroon.

[31] Resurreccion B.P., Sajor E.E. and Fajber E. (2008) Climate adaptation in Asia: knowledge gaps and research issues in South East Asia. A full report of the South East Asia Team, Climate Change Adaptation Southeast Asia, ISET-International and ISET-Nepal.

[32] Lead Afrique Francophone. (2009) E´tude de re´fe´rence dans la zone d'intervention du projet Lead sur les changements climatiques dans le de´partement de Bakel: Re´sultats et recommandations.

[33] Jena S.K., Kumar A., Brahmanand P.S., Mishra A., Sahoo N. and Patil D.U. (2015) Design and Development of Rubber Dams for Watersheds in the Climate Change Scenario. In: Singh, A., Dagar, J., Arunachalam, A. R. G., & Shelat, K. (eds). Climate Change Modelling, Planning and Policy for Agriculture. Springer, New Delhi. https://doi.org/10.1007/978-81-322-2157-9_11

[34] FAO. (2007) Adaptation to climate change in agriculture, forestry and fisheries: perspective, framework and priorities. Interdepartmental Working Group on Climate Change, Rome.

[35] Reddy P.P. (2016) Supplemental Irrigation. In: Sustainable Intensification of Crop Production. Springer, Singapore. https://doi.org/10.1007/978-981-10-2702-4

[36] Witt C., Pasuquin J.M.C.A., Mutters R. and Buresh R.J. (2005) New leaf color chart for effective nitrogen management in rice. Better Crops. 89.

[37] IFDC (International Centre for Soil Fertility and Agricultural Development). IFDC Report 2004-05. Alabama, USA.

[38] Roy A .H. and Groot J.J.R. (2009) Meeting Africa's fertilizer challenge: key to food security. 15th AFA International Fertilizers Forum & Exhibition. Cairo Semiramis Intercontinental Hotel, Egypt.

[39] Globally Important Agricultural Heritage Systems (GIAHS). 2013. Favourable eco-environmental conditions through rice-fish culture in China. (available at http://www.giahs.org/giahs-sites/south-east-asia/rice-fishculture-china/en/)

[40] Armstrong D.V., Hillman P.E., Meyer M.J., Smith J.F., Stokes S.R. and Harner J.P.I.I.I. (1999). Heat stress management in free stall barns in the western US. Proceedings of the 1999 Western Dairy Management Conference. Department of Animal Sciences and Industry, Kansas State University, Manhattan, Kansas, pp. 87–95.

[41] 42.Collier R.J., Hall L.W. and Smith J.F. (2014) Intensive Livestock Systems for Dairy Cows. In Climate Change Impact and Adaptation in Agricultural Systems (eds Fuhrer J., Gregory, P.J.). CAB International. pp. 110-122. https://doi.org/10.1079/9781780642895.0110