JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Boosting local food systems by identifying climate-resilient indigenous paddy cultivars and indigenous farming knowledge in Manipur, India.

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Abstract: Giving the local food systems a boost and conserving the associated indigenous knowledge possessed by the people of the land is a crucial step towards achieving resilient food systems. The north eastern Indian state of Manipur extends from the foothills of the Himalayan range and is the border to Myanmar. Owing to its unique geography of being located at the conflux of the Himalayan and Indo-Burma biodiversity hotspots with a population dominated by the indigenous people, and the long awaiting research attention towards it, the state becomes crucial to be considered for this study. Through an extensive ethnographic data along with quantitative yield data collected over a span of two years from the farming communities, this paper attempts to shed light on identified indigenous paddy cultivars that are potentially resilient to climate change alongside weaving the indigenous knowledge possessed by the Meitei community.

***IndexTerms* - *Adaptation*, *Climate Change, Food Security, Indigenous knowledge, Resilience*.**

I. LAND, AGRICULTURE AND FOOD

Land is the finite resource base which makes it possible to produce what we consume and with the growing population which is projected to reach 9.8 billion people by the year 2050 (World Resources Report, 2018), it is all the more crucial to manage it carefully. The current practice of more industrialized forms of agriculture has disrupted the systems that keep Earth in the desirable Holocene state or a more environmentally stable state (Rockström et al., 2009). Although land surface activities such as agriculture, along with forestry and other land use are major contributors to global terrestrial greenhouse gas emissions, accounting to about 23% of anthropogenic emissions (IPCC, 2019) of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), land is also a major carbon sink. The total net land-atmosphere flux of CO_2 on both managed and unmanaged lands very likely provided a global net removal from 2007 to 2016 according to models (IPCC, 2018). However, with the increasing imbalance between the emissions and sink process, agriculture and its allied sectors such as horticulture, fisheries, and forestry have also become most vulnerable to the impacts of climate change, which in turn will affect the global food systems. For instance, the horticulture sector gets affected by climate change with visible disruptions in the natural synchronicity between temperature and photoperiod, leading to higher respiration rate, altered rate of photosynthesis and other subsequent biological behaviour (Dixon et al., 2014; Malhotra, 2017). Climate change has become one of the greatest challenges in achieving food security.

Food systems encompass the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption and disposal of food products that originate from agriculture, forestry or fisheries (Unger & Wooten, 2006; Rogers et al.2016). Following the work of Berkes et al. in 2003, and that of Ericksen in 2008, food systems could be understood as social–ecological systems, formed of biophysical and social factors linked through feedback mechanisms (cited in Tendall, 2015). The emerging population will need to be fed and for that agricultural area needs to be expanded to ensure food security, with the ultimate goal to achieve a sustainable food future. While the higher atmospheric concentrations of CO_2 have a direct impact on C3 crops by increasing photosynthesis and the efficiency of water use, the indirect impacts of climate change include reduced yield from agriculture and its allied sectors, lower production of natural resources, forest regeneration etc. which in turn will have a negative impact on the livelihood of the people (Challinor &Wheeler, 2007).

Land not only supports agriculture it also protects the biodiversity thriving on it. The land is also home to the indigenous people who possess vast knowledge that has been passed down through generations. Almost 22% of the global lands are occupied by the indigenous people (UNESCO, 2020). They have retained social, cultural, economic and political characteristics that are distinct from those of the dominant societies in which they live. This knowledge in discussion or 'indigenous sciences' as termed by Raymond Pierotti in his book Indigenous Knowledge, Ecology, and Evolutionary Biology (PFierotti, 2011) has been around since time immemorial; mostly developed through a long process of trial and error by different traditional societies. There is a need to recognize that the ecosystems and the social systems that use and depend on the natural resources are inextricably linked (Folke et al. 2010). This recognition of an interlinked socio-ecological system is significant for ensuring that basic human needs are met on a sustainable basis (Rai, 2007). The indigenous knowledge possessed by such communities has long been working as a conservation measure for the natural environment and is a social process which is inextricably linked to social and political institutions influencing resource management (Bates & Tucker, 2010).

This paper attempts to discuss steps towards identifying local paddy cultivars that are climate resilient and indigenous knowledge associated with farming through the findings of a project that was taken up in the remote north-eastern border state of Manipur, India.

II. THE PADDY PEOPLE- THE MEITEIS AND THEIR RICE

The importance of rice in the Meitei culture is such that daily colloquial exchange starts with the question *chak charabra?* whose nearest translation would mean "did you have your meal?". The word *Chak* translates to cooked rice in the native language of Meiteilon and it almost encompasses the definition of food here. The reply to this question not only provide us with a mere line of greeting someone but more so the cultural importance of food. As Murcott (1981) has rightly quoted Leach (1976) - "Food is an especially appropriate mediator because when we eat, we establish, in a literal sense, a direct identity between ourselves (culture) and our food (nature)".

Following the indigenous belief that the land is home to various deities, the beginning of a cropping season is marked by offering locally available fruits and flowers with a prayer to the *lam lai* or the gods of the country-side who shade off into Nature Gods controlling the rain, the primal necessity of an agricultural community (Hodson, 1908). These deities are believed to reside in the nearby forests and hence, the need for acknowledging the presence of the spirit in all things living and conserving their abode. The *Meitei* elders would determine the puddling time of the paddy field by leaving a banana pseudostem in the soil. Once the pseudostem starts decomposing, the field is considered ready for puddling. They adopt direct seeding of rice by priming with mud when there is lack of moisture in paddy fields. In indigenous epistemology, a thing is understood only when it is understood with all aspects of human experience, that is, the mind, body, emotion, and spirit (Kimmerer, 2002). Traditional practices are related to cultural traditions and bio cultural dynamics and can regenerate local food systems while increasing socio-environmental sustainability and resilience (FAO, 2009).

III. AGRICULTURE IN MANIPUR

Like most places in India, the economy of the state of Manipur (geographical coordinates 24.6637° N, 93.9063° E) is predominantly agrarian. As per the 2011 census, the sector contributes a major share to the total state domestic product and provides employment to about 22.13 percent of the population (MANENVIS, 2021). The Imphal or Manipur River meanders through the Manipur valley in a NW-SE direction and passes through a gorge flowing out of the state to join the Chindwin River in Myanmar. Manipur covers a geographical area of 22347 sq. km and is divisible into a central valley and the surrounding mountains (MASTEC, 2020). The valley accounts to 10% of the total area (2238 sq.km.) which is inclusive of lakes, wetlands, barren uplands and hillocks. The traditional *jhum* or shifting cultivation is practiced in the hills with paddy being the major field crop. The valley is oval shape with a NNW-SSE orientation and has a gentle slope towards the South measuring 798 m above m.s.l. at the extreme north and 746 m above m.s.l. at the southern end. Here, a more settled form of agriculture is practiced.

As per the ICAR data, the state has 0.18 million ha under rice cultivation, which covers both irrigated and rainfed areas (ICAR, 2007) and which is also the staple crop. With the global consumption of rice projected to increase by 69 Mt by 2029, it is expected to remain as Asia's staple food (FAO, 2020). Although on a global scale, the probable aggregate effect of climate change on paddy production is moderately low its regional impacts could be significant (Toriman et al., 2013). The summer ploughing is carried out prior to the arrival of the south-west monsoon since most the agriculture is rainfed (Ravindranath, et al. 2014). Although the state boasts of harbouring the largest freshwater lake in the region and numerous rivers draining into it, water still continues to be a scarce resource, at times, resulting in acute drought conditions (Business Standard, 2014; The Hindu 2016; The Northeast Toady, 2021). Local farmers who have achieved years of experience would closely observe daily changes in plant physical characteristics such as colour, plant leaves, wilting symptoms, etc., on the whole and not for individual plant and which also usually makes them know the location and timing of a host of significant biological events (Inglis, 1993) thereby helping them decide on scheduling the irrigation. Their experience also enables them to use precautionary strategies to protect against the possibility of catastrophic loss in the event of a climatic shock and thus optimize management for average or likely conditions, but not for unfavourable conditions (Avecedo et al., 2020).

IV. RESEARCH METHODOLOGY

The experiment comprised of both qualitative as well as quantitative part. More than 200 farmers from more than 30 villages were the primary source of data during the initial phase of the project. These villages/blocks/farmers were identified through the secondary data collected from the state agriculture and allied departments/Krishi Vigyan Kendras (KVKs). Qualitative ethnographic data was obtained through open-ended interviews describing the farmers lived experiences in their respective farmlands. Additionally, close-ended questions were included to obtain yield data on potential indigenous paddy cultivars. Purposive sampling method was adopted to select the farmers participating in the on-farm trials (OFTs). Meteorological data was obtained from the ICAR Research Complex for the northeastern hills (NEH) region, Manipur Centre, Imphal.

Accordingly, twenty-one potential paddy cultivars were examined during the on-station trial (OST) of the cultivars in the *Kharif* season of 2019 at the College of Agriculture, CAU Imphal, Manipur. The cultivars were transplanted during mid-August in a gross field area of 405m2 with a per plot area of 15m2. The primary tillage was carried out with cultivator, followed by two cross ploughing and puddling with rotavator. 50% of N and 100% of P and K were applied during puddling. The remaining 50% of N was applied during active tillering stage. The average maximum monthly temperature recorded during the cropping period was 28.7°C with an average rainfall of 123.8 mm.

Eight of them were further identified based on their yield performance. These eight cultivars comprised of four upland cultivars *viz*. Takanu, Sangmare, Buthou, and Narnem and four shallow land cultivars *viz*. Akhanphou, Kakchengphou, Thangjingphou, and Moirangphou. They were further standardized through OST as well as in the farmers' field through on-farm trials (OFT) during the *Kharif* season of 2020. The sowing was done towards the end of July with an average maximum monthly temperature recorded at 27.5°C with an average rainfall received during the cropping period was 195.4 mm. Further OFTs were conducted during the *Kharif* season of 2021 in thirty different villages from five districts under supervised adoption of a recommended package of practices of paddy cultivation. Out of the five districts, four districts belong to the valley while one district belongs to the hill. Six farmers from six different villages from each districts were provided with paddy seeds and inputs of the eight cultivars (0.125 ha for each cultivar) to be screened along with seeds of Tampha Phou (control variety) for conducting the OFTs. The paddy cultivars were directly seeded during the first week of June, 2021 in all the villages with a recommended dose of 60:40:40 NPK kg/ha along with one chemical and one mechanical weed control practice. Average maximum monthly temperature recorded was 28.5°C with an average rainfall received during the cropping period was 196.5 mm.

V. RESULTS

Differences in the mean yield of the paddy cultivars as compared to the control variety, Tampha Phou, replicated in the five different districts are presented in Table 1 and Table 2.

Yield of different local paddy cultivars under different districts of Manipur under rainfed conditions.

V_1 - TamphaPhou (control var.)
V_2 - AkhanPhou
V_3 - KakchengPhou
V_4 - ThangjingPhou
V_5 - MoirangPhouYenthik
V_6 - Takanu
V_7 - Narnem
V_8 - Buthou
V_9 - Sangmare

R_1 – Imphal East
R_2 – Imphal West
R_3 – Bishnupur
R_4 – Thoubal
R_5 – Churachandpur

Table 1. Plant height, number of effective tillers and number of filled grains per panicle different local paddy cultivars under different districts of Manipur under rainfed conditions.

Varieties	Plant Height (cm)	Effective tillers/plant	Filled grains/panicle
V_1	127.40	23.60	168.20
V_2	124.60	15.80	113.00
V_3	145.20	10.80	88.40
V_4	136.40	11.60	89.80
V_5	138.60	14.20	104.60
V_6	131.20	4.40	36.60
V_7	126.40	5.40	40.40
V_8	125.60	5.80	43.00
V_9	123.60	4.40	33.80
Sed	**1.46**	**0.66**	**2.34**
CD (p = 0.005)	**3.09**	**1.40**	**4.96**

Table 2. Grain Yield, Straw Yield and Harvest Index of different local paddy cultivars under different districts of Manipur under rainfed conditions.

Varieties	Grain Yield (Kg ha^{-1})	Straw Yield (Kg ha^{-1})	Harvest index
V_1	5511.75	9739.19	0.57
V_2	3773.00	7000.03	0.54
V_3	2987.25	8157.34	0.37
V_4	3016.50	7662.95	0.39
V_5	3529.00	7786.55	0.45
V_6	1233.50	7056.21	0.17
V_7	1376.75	7101.15	0.19
V_8	1490.00	7370.82	0.20
V_9	1154.25	6943.85	0.17
Sed	**111.06**	**257.77**	**0.017**
CD (p = 0.005)	**235.44**	**546.46**	**0.036**

VI. DISCUSSION

The data presented revealed that significantly higher grain yield (5511.75 kg/ha) was obtained from the control variety, Tampha Phou (CAU R1) as compared to the local paddy cultivars. Tampha Phou is an improved variety developed by the Central Agricultural University (CAU) located in Imphal, Manipur. Among the shallow land cultivars, comparatively higher average grain yield was given by Akhan Phou (3773.00 kg/ha) followed by Kakcheng Phou (3529.00 kg/ha), Thangjing Phou (3016.50 kg/ha) and Moirangphou Yenthik (2987.25 kg/ha). The cultivars were grown in the valley where the soil is derived from deep to very-deep alluvium and are poorly to moderately-drained. Due to the high humus content (Department of Horticulture & Soil Conservation, 2021) they are slightly acidic and medium levels of phosphate is available to the plants.

One anomaly of Thangjingphou at Lamlai (Imphal-East district) recorded a yield of 1160 kg/ha. The yield variability under varied agro-ecology were also narrow in Akhan Phou (18%) and Kakcheng Phou (19.4%) showing higher tolerance capacity to varied agro-ecosystem while the other two cultivars varied above 30%.

The upland cultivars were cultivated in the hilly district of Churachandpur which is located at a distance of 61.5km away from the capital city of Imphal. The soil in this part of the state is of the type Typic Hapludults and is enriched with clay and organic carbon with high exchangeable Ca^{2+} and Mg^{2+} content

(Sahoo et al., 2020). Among the upland cultivars, highest yield was given by Takanu (1490.00 kg/ha) which was on par with the yield given by Narnem (1376.75 kg/ha). Relatively lower yield of 1233.50 kg/ha and 1154.25 kg/ha was obtained from Buthou and Sangmare respectively. It is observed that there is a higher yield of Tampha Phou, as compared to the yield of indigenous paddy cultivars. This observation is also supported by the findings of Jyothi, et al (2019) and Phapuma et al. (2020) where they have reported similar findings while studying the yield characteristics of indigenous paddy cultivars in North and North Eastern regions of Thailand.

VII. CONCLUSION

The rapidly changing climate and its impact on the crop production have redirected us to look for alternatives in our old and indigenous ways of identifying and growing crops. It is evident that the indigenous cultivars possess the resilience to climatic stress and could perform well with the right inputs. With advances in agricultural studies we are now able to discover more landrace paddy which have immense potential to be adopted in varied agro-ecological sites and could provide us with future alternatives in cases of food scarcity. Local crops are more likely to adapt to the changes in its surroundings than crops which are sourced from outside the region. In the case of Manipur, it could be well comprehended that the state is endowed with a rich natural resource base on which the majority of the population depends on for their subsistence. This high dependence of the state on its natural resources has rendered the region all the more vulnerable to the impacts of climate change.

The United Nations in 1986 has already recognized the significance of the indigenous people and they are also the key players in the achievement of the sustainable development goals. It is through them that the world could unlock the answers to combating climate change. Till date most of the research work is challenged with the lack of the inclusion of the indigenous people and their associated knowledge on land and the natural environment in general. The scientific community and the world would benefit greatly with a more active involvement of the various research bodies with the indigenous communities. Science will now have to mingle with the abstract and the abstract with science. However, this involvement must be treaded carefully so that it does not lead to the over-exploitation of the newfound untapped resources and the intellectual rights associated with a community. The sole purpose of this exploration should not result in the molding of the entire ecological knowledge to our whims, an error that has led the world to where it is now.

VIII. ACKNOWLEDGMENT

This research was funded by the Department of Science & Technology (DST), Government of India, for a NMSHE project under the HICAB Programme.

REFERENCES

1. Acevedo, M., Pixley, K., Zinyengere, N., Meng, S., Tufan, H., Cichy, K., Bizikova,L., Isaacs, K., Ghezzi-Kopel, K., Porciello, J.2020. A scoping review of adoption of climate-resilient crops by small-scale producers in low- and middle-income countries. Nature Plants. https://doi.org/10.1038/s41477-020-00783-z
2. ANI. (2014, April 23). Scarcity of water in Manipur. The Business Standard. https://www.business-standard.com/article/current-affairs/scarcity-of-water-in-manipur-114042300728_1.html
3. Arneth, A., F. Denton, F. Agus, A. Elbehri, K. Erb, B. Osman Elasha, M. Rahimi, M. Rounsevell, A. Spence, R. Valentini, 2019: Framing and Context. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press.
4. Bates, G. D., Tucker, J. 2010. Human Ecology: Contemporary Research and Practice, Springer, New York.
5. Beesabathuni, K., Askari, a.S., Bajoria, M., Bloem,M., Gavin-Smith,B., Hamirani,H., Kraemer,K., Kumari,P., Lingala,S., Milan,A., Tshering,P., van Zutphen, K.G., Woltering, K.. 2021. Food Systems Innovation Hubs in Low-and-Middle-Income Countries. UN Food Systems Summit. https://sc-fss2021.org
6. Berkes F, Sacred Ecology, (Routledge), New York, 2008, 3- 12.
7. Challinor, A.J. and Wheeler, T.R.2008. Crop yield reduction in the tropics under climate change: Processes and uncertainties. Agricultural and Forest Meteorology, **148**, 343–356.
8. Cho, R. 2012. State of the Planet: AGRICULTURE, How Green is Local Food Columbia Climate School, Columbia University, New York.
9. Chodur,M.G., Zhao,X., Biehl,E., Mitrani-Reiser, J., Neff, R..2018. Assessing food system vulnerabilities: a fault tree modeling approach. BMC Public Health, **18** (817). https://link.springer.com/article/10.1186/s12889-018-5563-x

10. Center for Climate and Energy Solutions. 2019. What is Climate Resilience, and Why Does it Matter. CLIMATE ESSENTIALS. https://www.c2es.org/document/what-is-climate-resilience-and-why-does-it-matter/
11. Clark, M., Tilman, D. 2017. Comparative analysis of environmental impacts of agricultural production systems, agricultural input efficiency, and food choice. Environ. Res. Lett. 12 064016. https://doi.org/10.1088/1748-9326/aa6cd5
12. Department of Horticulture & Soil Conservation, 2021. The Soils: Distribution and Classification of Soils Characterisation of Soils Under Different Agro -Ecological Subregions. Government of Manipur. https://horticulture.mn.gov.in/soil_of_manipur.html
13. Dixon, G.R.., Collier, H.R., Bhattacharya, I.2014. An Assessment of the Effects of Climate Change on Horticulture. *Horticulture: Plants for People and Places*, ***2***, 817-857. https://doi.org/10.1186/s12889-018-5563-x
14. Dove, R.M. 2006. Indigenous People and Environmental Politics. Annual Review of Anthropology.**35**, 191–208.
15. ENVIS Hub Manipur. 2021. Water Resource. Directorate of Environment, Govt. of Manipur. http://www.manenvis.nic.in/Database/WaterResource_2704.aspx?format=Print
16. Etchart, L.2017. The role of indigenous peoples in combating climate change. Palgrave Commun 3, 17085. https://doi.org/10.1057/palcomms.2017.85
17. FAO.2020. OECD-FAO AGRICULTURAL OUTLOOK 2020-2029. Rome. Food and agriculture must too. Food and Agriculture Organization of The United Nations. pp-130.
18. FAO.2016. World Food Day. Climate is changing. Rome. Food and Agriculture Must Too. Food And Agriculture Organization Of The United Nations.
19. Fawibe O.O., Honda, K., Taguchi, Y., Park, S., Isoda, A. 2018. Greenhouse gas emissions from rice field cultivation with drip irrigation and plastic film mulch. Nutr Cycl Agroecosyst, https://doi.org/10.1007/s10705-018-9961-3
20. Hodson, T.C. 1908.The Meitheis. David Nutt, 57, 59, Long Acre. London.
21. ICAR. 2007. State-specific Technological Interventions for Higher Agricultural Growth. ICAR New Delhi. https://icar.org.in/files/state-specific/forward.htm
22. India Meteorological Department.2020. ANNUAL REPORT. https://mausamjournal.imd.gov.in/index.php/MAUSAM/Annualreport
23. Johannes, R.E. 1993.Integrating Traditional Ecological Knowledge and Management with Environmental Impact Assessment. In Inglis, T.J. Traditional Ecological Knowledge Concepts and Cases. 33-40. International Program on Traditional Ecological Knowledge and International Development Research Centre. Ottawa.
24. Liang, J., Lu, X.,Hou, E., Hoffman, M.F.,Luo, Y. 2021. Country-level land carbon sink and its causing components by the middle of the twenty-first century. *Ecological Processes*.**10**(61). https://doi.org/10.1186/s13717-021-00328-y
25. Jyothi S.S., Loukham D, Singh K. N., Singh R, Singh R. J., Hemochandra L., Singh M. K.,and Ram D., 2019. Prioritization of Stakeholders in Diffusion of CAU-R Series Varieties in Manipur. *Economic Affairs.* **64**(2): 271-280.
26. Laithangbam, I. (2016, May 19). Manipur facing acute drinking water shortage. The Hindu. https://www.thehindu.com/news/national/other-states/manipur-facing-acute-drinking-water-shortage/article5819061.ece
27. Laishram, J., Saxena, K,G.,K. S. Rao. 2020. Rice cultivar diversity, associated indigenous knowledge and management practices in a lowland village landscape from north-eastern India. Vegetos. https://doi.org/10.1007/s42535-020-00097-7
28. Lynch, J. 2019. Agricultural methane and its role as a greenhouse gas. Food Climate Research Network, University of Oxford.
29. M. Allen, H. de Coninck, O. P. Dube, O. Hoegh-Guldberg, D. Jacob, K. Jiang, J. A. Revi, Rogelj, J. Roy, P.Tschakert, D. Shindell, W. Solecki, M. Taylor, H. Waisman, S. Abdul Halim, P. Antwi-Agyei, F. Aragón–Durand,M. Babiker, P. Bertoldi, M. Bindi, M. Buckeridge, S. Brown, I. Camilloni, A. Cartwright, W. Cramer, P. Dasgupta, A. Diedhiou, R. Djalante, W. Dong, K. Ebi, F. Engelbrecht, S. Fifita, J. Ford, P. Forster, S. Fuss, V. Ginzburg, J. Guiot, C. Handa, B. Hayward, Y. Hijioka, JC. Hourcade, S. Humphreys, M. Kainuma, J. Kala, M. Kanninen, H. Kheshgi, S. Kobayashi, E. Kriegler, D. Ley, D. Liverman, N. Mahowald, R. Mechler, S. Mehrotra, L. Mundaca, Y. Mulugetta, P. Newman, C. Okereke, A. Payne, R. Perez, P. F. Pinho, A. Revokatova, K. Riahi, S. Schultz, R. Séférian, S. I. Seneviratne, L. Steg, A. G. Suarez Rodriguez, T. Sugiyama, A. Thomas, M. V. Vilariño, M. Wairiu, R. Warren, G. Zhou, K. Zickfeld, 2018, Technical Summary. In: *Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)]. In Press.
30. Malhotra, S.K. 2017. Horticultural crops and climate change: A review. Indian Journal of Agricultural Sciences **87** (1), 12–22.
31. Mendelsohn, R. 2009. The Impact of Climate Change on Agriculture in Developing Countries. Journal of Natural Resources Policy Research, **1** (1), 5–19.
32. Mendelsohn, R. 2014. The Impact of Climate Change on Agriculture in Asia. Journal of Integrative Agriculture, **13**(4), 660-665.
33. Murcott, A. 1982. The cultural significance of food and eating.Proc. Nutr. Soc. https://doi.org/10.1079/PNS19820031
34. Pierotti R, Indigenous Knowledge, Ecology, and Evolutionary Biology, (Routledge), New York, 2011.
35. Phapumma A., Monkham T., Chankaew S., Kaewpradit W., Harakotr P and Sanitchon J., 2020. Characterization of indigenous upland rice varieties for high yield potential and grain quality characters under rainfed conditions in Thailand. *Annals of Agril. Sci.* **65**: 179-187.

36. Rai, C.S. 2007. Traditional Ecological Knowledge and Community-based Natural Resource Management in Northeast India, Journal of Mountain Science, 4 (**3**) 248-258.
37. Ravindranath, H.N., Rao,S., Sharma, N., Nair, M., Gopalakrishnan, R., Rao, A.S., Malaviya, S., Tiwari, R., Sagadevan, A., Munsi, M., Krishna, N., Bala, G. 2011. Climate change vulnerability profiles for North East India. Current Science, **101**, 384-394.
38. Rogers, A., Ferguson, M., Ritchie, J., Van Den Boogaard, C., Brimblecombe, J. 2016. Strengthening food systems with remote Indigenous Australians: stakeholders' perspectives. *Health Promotion International*. **33** (1), 38–48 https://doi.org/10.1093/heapro/daw047
39. Rockström, J., Steffen, W., Noone, K., Persson, A., Chapin, F.S., Lambin, E.F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H.J., Nykvist, B., de Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sorlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B.H., Liverman, D., Richardson, K., Crutzen, P., Foley, J.A., 2009. A safe operating space for humanity. Nature, **461** (7263), 472–475.
40. Sahoo, S., Vasu, D., Paul, R., Sen, K.T., Ray, S.K., Chandran, P..2020. Acid Soils of Manipur of the North-eastern Region of India: Their Mineralogy, Pedology, Taxonomy and Edaphology. Clay Research, **39**, 31-43.
41. Semba, R.D., de Pee, S., Kim, B., McKenzie, S., Nachman, K., Bloem, W. M. 2020. Adoption of the 'planetary health diet' has different impacts on countries' greenhouse gas emissions. Nature Food**,** **1**, 481–484. https://doi.org/10.1038/s43016-020-0128-4
42. Smith, P., D. Martino, Z. Cai, D. Gwary, H. Janzen, P. Kumar, B. McCarl, S. Ogle, F. O'Mara, C. Rice, B. Scholes, O. Sirotenko, 2007: Agriculture. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
43. Tendall, D.M., Joerin, J., Kopainsky, B., Edwards, P., Shreck, A., Led, Q.B., Kruetlia, P., Grant, M., Six, J.2015. Food system resilience: Defining the concept. Global Food Security. **6**. 17–23. http://dx.doi.org/10.1016/j.gfs.2015.08.001
44. The Royal Society. 2018. Greenhouse gas removal. DES5563_1 http://royalsociety.org/greenhouse-gas-removal
45. TNT. (2021, March 18). Manipur: Imphal likely to suffer water shortage, says PHED. The Northeast Today. https://thenortheasttoday.com/states/manipur/manipur-imphal-likely-to-suffer-water-shortage-says-phed/cid2511874.htm
46. Toriman, E.M., 2013.Paddy Production and Climate Change Variation in Selangor, Malaysia. Asian Social Science.9 (14). http://dx.doi.org/10.5539/ass.v9n14p55
47. UNESCO, Indigenous Peoples, 2020. https://en.unesco.org/indigenous-peoples
48. Unger, S.Wooten, H.2006.A FOOD SYSTEMS ASSESSMENT FOR OAKLAND, CA: TOWARD A SUSTAINABLE FOOD PLAN. Oakland Mayor's Office of Sustainability http://oaklandfoodsystem.pbworks.com/f/Oakland%20FSA_6.13.pdf
49. Wang, J., Vanga, K, S., Saxena, R., Orsat, V., Raghavan, V.2018. Effect of Climate Change on the Yield of Cereal Crops: A Review. Climate, **6**(2), 41; https://doi.org/10.3390/cli6020041