Participatory GIS *(PGIS)* Approach for the Development of Community-based Climate Smart Sustainable Agriculture Models in the Semiarid Regions of Southern India

L. Muralikrishnan[1*], N. Manikandan[2], J. Prasanth Tej Kumar[3], Anjoo Yumnam[4], Azeze Seyie[5], Maharishi Tomar[6] and P. Venkatesh[7]

[1]Division of Agricultural Extension, ICAR-IARI, New Delhi, India.
[2]Agricultural Meteorology All India Coordinated Research Project on Agro meteorology (AICRPAM), ICAR – CRIDA, Hyderabad, India.
[3]Agricultural Biotechnology, ICAR - Central Citrus Research Institute, Nagpur, India.
[4]Agricultural Economics, ICAR-RC-NEH for Meghalaya, India.
[5]Spices and Plantation crops, ICAR- RC for NEH Region, Umiam, Meghalaya, India.
[6]Plant Biochemistry, ICAR- IGFRI, Jhansi, India.
[7]Extension Systems Management Division, ICAR – NAARM, Hyderabad, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

The climate change impacts primarily affect the developing country's agriculture and natural resources which is highly vulnerable due to population pressure. Using Participatory GIS (PGIS) approach, first hand information on farmers needs, availability of resources, location specific problems and researchable issues were identified in Thattaparai village in Gudiyatham taluk of Vellore district of Tamil Nadu. In the present study, the Participatory Rural Appraisal tools like transect walk, agro-ecological mapping, social mapping, time trend, gender analysis, time line,

_____

Corresponding author:E-mail ; metsate@gmail.com

livelihood analysis, seasonal calendar, technology mapping etc were employed to understand the farmers real need and problems of the study village. The Rank Based Quotient (RBQ) and Value Based Indicator (VBI) were calculated to find out the ranking of the problems in that village. Through analysis, it was found research gaps of water scarcity, increased atmospheric temperature, cropping system practices, heat waves causes extreme heat stress in crops and the extension gaps of poor awareness about water conservation and maintenance of water bodies, water harvesting process, crop insurance and weather forecasting and cultivation of less water consuming crops like sorghum, millets, pulses, oil seeds and value addition. The authors suggested solution to the identified problems of the village under study and also gave suggestion to formulate community- based climate smart sustainable agriculture model projects for inclusive development of the region.

1. INTRODUCTION

The global atmospheric temperature would increase by 1.5°C than pre-industrial era between 2030 and 2052, if it rise at the current rate as predicted by IPCC [1]. It is mainly due to GreenHouse Gas (GHG) emissions, deforestation and natural resources degradation. The climate change impacts have further resulted in increased events of droughts, floods, irregular patterns of precipitation, heat waves and other extreme happenings throughout the globe. It resulted in the economic loses of USD 225 billion across the world in 2018 [2]. Further, the climate change impacts primarily affect the developing country's agriculture and natural resources which is highly vulnerablele due to population pressure [3]. In developing countries like India as the increased population may pressure on agricultural lands to meet the growing food demands particularly in the arid and semiarid agro ecological region [4]. To cope up with the rising needs of growing population under the changing climatic atmosphere and degraded natural resources farming systems. The preference should be given in to climate smart agricultural practices to sustain the agricultural production and effectively manage the natural resources and mitigate the climate change impacts. The strategy also supports to achieve the major sustainable development goals (SDG) by 2030 [5].

To address the impact of climate change and natural resources degradation related issues to ensure sustainable food security implementation process should be done at the ground level through possible climate smart agriculture and natural resources management practices through participatory GIS *(PGIS)* for assessing the problems in climate change impacts and Natural Resources for community- based climate smart agriculture and Natural Resources Management (NRM) practices [6].

1.1 Importance of Participatory Rural Appraisal (PRA) tools

The Participatory Rural Appraisal (PRA) tools could assess the absolute farming system specific climate change impacts and natural resources degradation issues and extension related problems to come up with the possible solutions for short and long term benefits. PRA tools useful to understand the problems of the farmers. It is a systematic, semi structured activity conducted on site, by a multidisciplinary team. It is an important tool to comprehend the technology adoption profile in a cropping system, to get first-hand information about their needs, resources available (soil type, water resources, land use, land pattern and topography of different life support system) to identify location specific problems and re-searchable issues to come up with tangible possible solutions drawn as an action plan [7]. It is a good technique to help the community members make an appraisal of their livelihood issues and opportunities. For formulation of research plan to address the research and extension problems through appropriate social cohesive and people participatory actions at ground level. Gouranga Kar et al. [8], Rajula Shanthy [9] and Anirban Mukherjee [10] employed PRA tools for identification of problems of the famers of rainfed upland system of Dhenkanal district of Odisha, Coimbatore district of Tamil Nadu and Patna district of Bihar, respectively.

1.2 Importance of Geographical Information System (GIS)

Geographic Information Systems (GIS) play very important role to effectively map the climate and

natural resources degradation related issues. The GIS based satellite sensor enabled digital technologies access to identify location specific agro-ecological issues for formulation of appropriate climate smart agricultural and natural resources management practices. It can also help in future predictions for the vulnerable agro-ecosystems and suggesting to help in preparedness and planning of managing the agro-ecosystems for extreme events such as water scarcity, cyclones, heat waves, drought, floods and so on. At the same time, the information is often seen as incompatible with less people participation are mostly seen as incompatible for finding the research and extension projects to make a need based projects for adoption of "best practices and technologies" to solve the climate and natural resource management related practices for enhanced adoption of climate smart farming practices and enhancement of natural resources through appropriate Natural Resource management (NRM) practices. Hence, the People participatory GIS *(PGIS)* showed to be an effective tool for integrating absolute natural resources information to help and motivate various stakeholders with the help of people participatory extension delivery mechanisms for sustainable climate smart agricultural and natural resources management practices through elaborate detailed geo-referenced base maps particularly in the source poor semi-arid region agro ecologies of southern India [11].

2. METHODOLOGY

The research study was conducted intensively in the Thattaparai village in *Gudiyatham* block of Vellore district of Tamil Nadu. The ICAR – Multidisciplinary Agricultural scientists from Plant Biochemistry, Agricultural Meteorology, Agricultural Economics, Agricultural Extension, Agricultural Biotechnology and Horticulture under the guidance of National Academy of Agricultural Sciences, Hyderabad, took research works of Geographical Information System (GIS) based Participatory rural appraisal (PRA) tools to assess the problems in climate change impacts and Natural Resources for community- based climate smart agriculture and Natural Resources Management (NRM) practices in the semiarid regions of southern India. The team had utilized the Participatory GIS *(PGIS)* tools of Geographical Information System assisted Transect walk, Agro-ecological map, Resource map, Time line, Seasonal calendar (activities) and Seasonal analysis (problems), Bio-resource

flow, Indigenous technical knowledge, Technology map, Social map, Consequences diagram and problem prioritization along with several focus group discussions and opinion leaders.

The primary and secondary data collection also carried with the support of semi-structured interview schedule for assessment of the village to find out the climate change impacts and natural resources management related research and extension issues in agriculture, felt needs of the farmers, resources availability and accessibility status, livelihood status, technologies adoption and rejection status, problems and prospects related to agriculture, horticulture and animal husbandry, opportunities to rectify the climate related and natural resources degradation related issues. Finally, the information was verified by triangulation among various key informants in addition to on-site observation by the team members. It was very useful to identify the climate and natural resources related to adopt suitable climate smart agricultural practices to make that village as a climate smart agricultural village for effective climate resilience and Natural resources management in the village. It may support to replicate the "climate smart agricultural model villages" with location and farming systems' specificity in the other semiarid region of Southern India as a socio- economically, eco-friendly and sustainable agricultural production systems.

2.1 The Problems Identification

The problem identification technique was used to identify and prioritize the farmers' problems prevailing in agricultural sector in the village. For this purpose, 25 farmers were identified from the village representing all sections of the village using Rank Based Quotient (RBQ) and Value Based Index (VBI) technique. The RBQ was calculated through using following formulae as proposed by Sabarathnam [12].

$$RBQ = \sum f_i (n+1 -i) / (N \times n) \times 100$$

Where, fi = Frequency of agrarians for the ith rank of the attribute N = No. of farmers communicated for factor identification n = Maximum no. of ranks given for various factors. i = Rank of the attributes Preferential ranking technique, to assess and prioritize the constraints of the villages' climate related issues on the basis of overall magnitude value [13]. The

Value Based Index (VBI) using following formulae:

VBI = (RBQ x average loss experienced X Area of crops cultivation / Climate related problems identified) X 100

After identifying and ranking the problems, some of the farmers were interviewed again to get an idea about the possible causes of each of the problems related to climate change related issues to formulate the climate smart agriculture oriented research project to mitigate the problem through adoption of climate smart agricultural practices.

3. RESULTS AND DISCUSSION

The geographical information system based transect walk (Fig. 1) exercises helped to identify the topographical pattern, land and water resources use pattern for various crops, livestock and different other agro-ecological components of major weeds, trees, and other social institutions. The village comprises of 6 hamlets, which is surrounded by Synagunta reserve forest in the north side. The rain fed agriculture and horticultural crops, presence of more percolation ponds covered with *Prosopis juliflora* (Ground water abstraction) and check dam with better soil properties were also observed in the village. The main climate and natural resources related problems were the scarcity of water, which is due to decrease in quantum of rainfall over the years and erratic distribution and poor watershed based water management practices.

The transact walk helped the multidisciplinary research team to categorize the different ecological features to draw an agro-ecological map to identify the various agro ecological resources of the study village. The major crops grown were groundnut, sugarcane, paddy and pulses, coconut, banana, papaya, tomatoes and green leafy vegetables. The livestock components of cattle, goats and sheep were also observed and most of the farmers practiced homestead farming. The fruit and social forest trees like custard apple, tamarind, neem, *subabool* etc. also observed in the village. But, due to poor water availability, impact of severe drought and practicing traditional agricultural practices, improper application of agricultural inputs led to poor production and productivity in the farming systems. This map also supported with the satellite based geographical information system map for triangulation and useful for effective integration of natural resources to better social and economic development purposes in a sustainable manner.
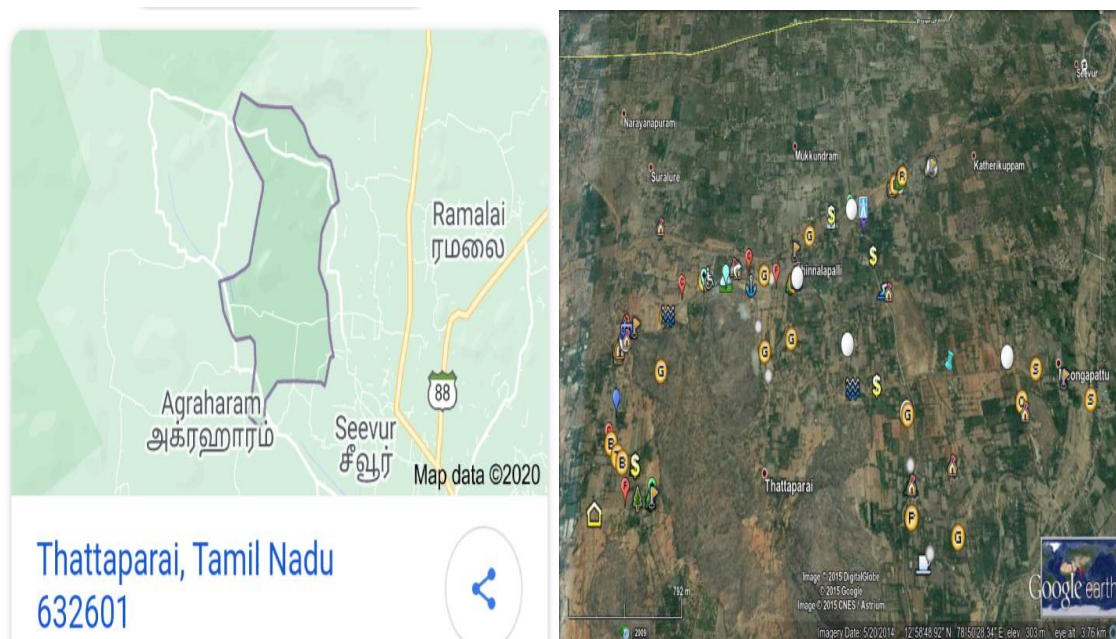

Fig. 1. The GPS based transect map and google map of the Thattaparai village

4

3.1 Resource Map

Resource map represent that all the agricultural resources are existing in the village [14]. The resource map supports to identify the existing village resources utilization pattern to assess the climate and natural resources related issues to access the resources for potential climate smart agricultural practices with the combination of both the natural and man-made resources of main crops, trees, animals, farm implements, communication items, human resources of skilled labour, technical manpower (Horticultural Officer (HO) and Village Administrative Officer (VAO) etc. The Thattaparai village resource map gives an idea of the various resources utilization pattern as compare to the enhanced sustainable climate smart agricultural and other livelihood opportunities. The Thattaparai resource map majorly highlighted Water resources of one "Chandan Eri" (Irrigation Tank), 16 percolation ponds and 24 check dams with the water table is 900 feet below the ground level. Further, one canal passing through the village which is coming from "Mortana" dam. The crop and animal husbandry practices were discussed earlier in the agro-ecological map. The agricultural implements and mechanization utilization pattern of several mini and big tractors, power sprayers, disc harrow, sugarcane crusher and electric motor pumps are available in the village.

The social resources of electricity connections, gas connections, telephone connections, internet, cell phone, cable connection, radio, and dish TV networks and the Institutional resources of village administrative office, post office, library, rural child care centre , government high school, and public ration shop and village level milk co-operative society with the available transportation facilities motor cycle, cycle, bus, tractor and bullock cart also helpful for transporting agricultural commodities and better standard living conditions of the village. This map also triangulated with the satellite based geographical information system map. The *PGIS* map helps to understand the existing resources utilization patterns and problems about the natural resources and climate change impacts in the village. the *PGIS* based resource mapping may support to adopt suitable climate smart and natural resources management based appropriate strategies for useful for effective integration of natural resources to better social and economic development purposes in a sustainable manner.

3.2 Time Line of the Thattaparai Village

Time line is used to know the Thattaparai village's historical changes in socioeconomic, technology diffusion and adoption, information regarding the important such as like the development in agriculture, animal husbandry [14]. From the time line of agriculture of Thattaparai village reported that, sugarcane and paddy are the two most important crops in Thattaparai. The sugarcane variety COC 740 introduced in the year 1970 and high yielding varieties of rice like IR8, IR50, IR20 were introduced during the green revolution period Table 1. In the year 2006, System of Rice Intensification (SRI) in rice was introduced to the village through trainings conducted by KVK and the method also increased the yield by about 30-40% as compared to the traditional method of rice cultivation. But, practical difficulties in preparing and maintaining special nursery (Dapog method) in SRI led to its decreasing adoption in the village. The villagers reduced the area under sugarcane and rice in the last 20 years due to non-availability of irrigation water and erratic rainfall distribution, drying up of river and decreasing groundwater level. In the year 1970 buffaloes were reared in Thattaparai village for milk production purposes then cross breeds like Holstein Friesian and Jersey was covered in the village for more milk with more fat content, substituted buffaloes in the village where more than 70 per cent of the people make lives out of agriculture.

3.3 Time Trend

Time trend was mostly based on the state level prices of the agricultural commodities price enhancement with the government policy regulations [14]. Mostly, as compare to other commodities, agricultural commodities prices have 2-4 times higher as compare to the prices of the year 1995. But, the agricultural labour charges increased 10 times higher than 1995-year average village agricultural wages due to the 100 days' rural employment guarantee scheme and agricultural input costs increased 3 to 5 fold times.

3.4 Seasonal Calendar and Seasonal Analysis

Seasonal calendar plays very important role to adopt appropriate climate smart agriculture practices in the farming systems in the semi-arid

regions where the rainfall patterns are skewed only in some seasonal rainy days [14]. The seasonal calendar depicts month-wise activities for agriculture based enterprises (crops/ animals etc.), abnormalities, threats, problems, abundance and shortage in a year. This method will help in identifying the months of peaks and slump of labour demand for different agricultural activities, incidence of pests and diseases, availability of water, fodder, etc. The gender disaggregated seasonal calendars indicate the differential involvement of men/women/children in these enterprises. Table 2 shows the gender disaggregated seasonal calendar of three important crops in Thattaparai, i.e. groundnut, spiny brinjal and finger millet. It is observed that men are involved in laborious activities like land preparation, fertilizer and micronutrient application, spraying of pesticides and harvesting whereas women are involved in those activities which are time consuming, cumbersome and that which requires skills like weeding, earthling up, sorting and drying of groundnut.

3.4.1 Bio-resource flow diagram

Bio-resource flow diagram reflects the inflow and outflow of farm produce and its by-products from and to the household. It explains the interrelationship between different farm enterprises that enable holistic planning for development of farm household. The Thattaparai village households' bio-resource flow diagram, mostly represent that the straw from paddy is used for cattle feed, Cow dung and Cow urine is used to prepare organic mixture of ingredient mostly used (Panchakavyam) for good crop performances. Cow dung mixed with straw waste and dried to prepare varatti (locally made fuel). Groundnut stover were dried and used as fodder for cattle, Vegetable by-products such as shots, leaves are used as fodder for cattle. Coconut husk is used as fuel, and the leaves are dried to make hut coverings. Leaves are also used for broom preparation. Further, cow milk, poultry egg and meat are mainly used for consumption purpose and excess produce is sold in market. Apart from the existing bio-resource flow, the bio-resource flow diagram also depicts some proposed bio-resource flow like back yard poultry, domestic level animal rearing and kitchen garden for further level effective utilization of animal wastes, crop residues, agricultural produce based on different crops for effective climate smart agriculture in the semiarid tropics' farming systems of southern India.

Table 1. Timeline of adoption of agricultural technologies in Thattaparai village

Year	Events
1970	Sugarcane CoC740 variety
1970	HF, Jersey
1970	Paddy variety IR8, IR50, IR20
1976	CoC772, CoC94077, CoC95066
1980	Power sprayer/ Rocker sprayer
1985	Check dams/ Tractor/ cultivator/ Bio gas plant
1985-86	Social Forest
1988	Bore well
1989	TV
1990	Percolation tank
1998	CoC86032/ Sugarcane hybrid
2000	Knapsack sprayer
2003	Paddy variety IR43, Co43, Co45
2005	Mobile phone
2005-06	Paddy thresher
2006-07	SRI
2007	VRL-2 Groundnut variety
2008	High school
2010	Kadiri-6 Groundnut variety
2011	Solar light
2012	Paddy trans planter
2013	Co51 Paddy variety
2015	Co6 Groundnut variety

Table 2. Seasonal analysis- activity and gender disaggregated calendar

Particulars	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Groundnut	L (♂)	S(♂/♀) FA (♂)	W(♀), Sp(♂)	W(♀),E(♀), MN(♂)	H(♂/♀)Sr(♂/♀)	D(♀)						
Brinjal		T(♀),FA(♂)	W(♀),E(♀), MN(♂)	Sp(♂)	H(♂/♀)							
Finger millet					L(♂), NS(♂), T(♀)	W(♀), FA(♂),	FA(♂)	H(♀) Th(♀) Cl(♀)		SPI(♂)		

S-Sowing	W- Weeding	E-Earthing up	H- Harvesting
D-Drying of groundnut	FA- Fertilizer Application	Sr- Sorting	L- Land Preparation
Sp-Spraying pesticide	MN- Micro nutrient Application	T-transplanting	NS-Nursery Sowing
Th - Threshing	Cl- Cleaning	SPI- Summer Ploughing	

3.5 Indigenous Technical Knowledge

Indigenous Technical Knowledge (ITK) mostly supported to control different pest and disease problems in crops, diseases in livestock and treatment of minor human ailments by the villagers. Thattaparai village ITKs, such as Neem kernel extract, Leaf juice of "*Eetti*" tree was used as a bio-pesticides in different crops. Practise of feeding two desi eggs wrapped in straw to cure fever in cow, Lemon juice + lime + hutamani mixture application to cure for mastitis, feeding a mixture of betel leaf, ginger, asafoetida and fenugreek and *Aloe vera* + turmeric paste to cure for foot and mouth disease in animal husbandry activities also supported to adopt less pesticide and climate smart agricultural practices in the semi-arid south Indian farming systems.

The Thattaparai village technology table represent the present level of agricultural technologies adoption status Tables 3, 4. It also supports to climate smart agricultural practices.

3.6 Livelihood Analysis

Livelihood Analysis is an analytical technique of exploring behaviours, decisions and coping strategies of households with different socio-economic backgrounds. The livelihood analysis is drawn for the families each representing a different wealth category. They were classified based on their land size, rich (>8 Acres), medium (1-8 Acres) and poor (<1 Acres or landless). The livelihood statuses of each category were analysed represent that, mostly the rich farmer practised commercial agriculture through cultivation of high value crops of Banana, sugarcane, the medium category farmer has gone for rice and groundnut. The poor category farmer practised along with agriculture, they practised cattle rearing and labour act ivies. Hence, their income level, assets status, expenditure patterns, saving patterns, decision making power and coping strategy also very good status for rich, moderately good for medium category and poor for poor category farmers. Hence, the the climate change impacts mostly affecting the poor category of farmer. Hence, the climate smart agriculture practise should be targeted marginal and small farmers of the farming systems of the semiarid regions of Southern India.

The most important method in Participatory Rural Appraisal (PRA) of social mapping explored the village people accessibility and utilization patterns of social infrastructures such as roads, drainage systems, schools, drinking-water facilities, etc [14]. it also gave information about the social stratification, demographics, settlement patterns, social infrastructure, etc.

Table 3. Technology table for cereal, oil seeds, sugarcane and livestock in Thattaparai village

SL.No.	Criteria	Technology	Status	Reason
1.	Sugarcane	COC740 variety	A	Resistance to Red rot, high productivity
2.	Cow	HF, Jersey	A	Improved milk productivity
3.	Paddy variety	IR8, IR50, IR20	A	Resistance to BPH, high productivity
4.	Groundnut	VRL-2 variety	A	High productivity
5.	Rice	SRI	A	High productivity, input use efficiency
6.	Forage crop	CO4	A	More milk production
7.	Cow	AI	A	Easy, cheap genetic selection

Table 4. Technology table of farm implements in Thattaparai village

SI.No.	Technology	Status	Reason
1.	Tractor	A	Easy plough High efficiency Can be operated in fields with intercrops
2.	Motor pumps	A	More efficient
3.	Drip irrigation	NA	No awareness
4.	Bore wells	A	Source of ground water for irrigation
5.	Hand and power sprayer	A	Efficient spray of pesticides
6.	Paddy thresher	A	Drudgery reduction

A-Adopted, NA-Not Adopted.

The process for social mapping helped to gather village information about caste based households' settlement patterns within the village, Social institutions and economy, family structure, patterns, and relationships, educational background of villagers, assimilation patterns, accommodation practices, leadership patterns, value systems of the village, social interactions, communication practices and leadership pattern to improve extension and advisory services in the Thattaparai village in *Gudiyatham* block of Vellore district of Tamil Nadu. The social map revealed the hamlets settlement patterns and the social cohesiveness level to identify various climate related issues to adopt various technologies for effective climate change adaptation and mitigation Fig.2.

3.6.1 Problem identification and prioritization technique

The problem identification technique was used to identify and prioritize the problems prevailing in agricultural sector in relation to climate change impacts for identifying effective adaptation strategies in the village Table 5. For this purpose, 30 farmers were identified from the village representing all sections of the village using RBQ and VBI technique There were 12 problems in agriculture were asked to rank the problems based upon the severity and percentage of loss they are personally facing by the problem. Since, the selected farmers represented all the sectors varying from large farmers, marginal farmers, small farmers and landless farmers, ranking pattern were also diverse from crops to animal husbandry. The extent of damage (per acreage)

to affected crops due to particular problem in the village was determined by the farmers. The average monetary losses for the village were calculated for each problem.

3.6.2 Prioritization of climate impacted problems

Based on the problem identification and prioritization technique, water scarcity, high temperature reduces crop yield, Poor soil testing and fertilizer management, Improper agricultural financial facilities, poor awareness of crop insurance and weather forecasting, poor cropping system practices, Agricultural products marketing issues, seasonal migration, Poor maintenance of water bodies, Heat waves causes extreme heat stress in crops, reduced rainfall distribution and fallowing of agricultural lands are the rank order issues in relation to climate change impacts in the Thattaparai village in *Gudiyatham* block of Vellore district of Tamil Nadu Table 6.

3.6.3 Perspectives of problems

The identified climate impacted and natural resources management related problems were classified into research and extension problems to make more in focus of the farmers to adopt effective climate smart in interventions in the Thattaparai village in *Gudiyatham* block of Vellore district of Tamilnadu as a model climate smart village through effective people participation in the semiarid tropics' farming systems of southern India.

Fig. 2. Farmers-subject matter specialists interaction meeting and social map of Thattaparai village

Table 5. Climate change impacts related problems identification

Sl. No.	Problems identified	Ranks					
		1	2	3	4	5	Total farmers
1.	Water scarcity	5	10	5	5	5	30
2.	Higher temperatures reduce crop yield	5	10	5	10	0	30
3.	Heat waves causes extreme heat stress in crops	0	0	5	10	15	30
4.	Poor soil testing and fertilizer management	0	10	10	5	5	30
5.	Seasonal migration	0	10	10	5	5	30
6.	Poor maintenance of water bodies	0	5	5	15	5	30
7.	Poor rainfall distribution	0	0	15	10	5	30
8.	Fallowing of agricultural lands	0	0	0	25	5	30
9.	Agricultural products marketing issues	5	5	10	5	5	30
10.	Poor cropping system practices	5	10	5	5	5	30
11.	Improper agricultural financial facilities	5	5	5	10	5	30
12.	Poor awareness of crop insurance and weather forecasting	0	0	15	10	5	30

Table 6. Rank based climate change impacts related problems categorization

Sl.No.	Problems Identified	RBQ	% Loss	VBI	Rank
1.	Water scarcity	85.9	25	2147.4	1
2.	Atmospheric temperature increased	87.9	12	1046.2	2
3.	Heat waves causes extreme heat stress in crops	71.8	3	215.4	10
4.	Poor soil testing and fertilizer management	84.6	10	846	3
5.	Seasonal migration	84.6	4	338.4	8
6.	Poor maintenance of water bodies	79.5	3	238.5	9
7.	Poor rainfall distribution	79.5	2	159.0	11
8.	Fallowing of agricultural lands	75.6	1	75.6	12
9.	Agricultural products marketing issues	84.6	4	338.5	7
10.	Poor cropping system practices	85.9	5	429.5	6
11.	Improper agricultural financial facilities	83.3	10	833.3	4
12.	Poor awareness of crop insurance and weather forecasting	79.5	6	477.0	5

3.6.4 Research gap

1. Water scarcity
2. Atmospheric temperature increased
3. Agricultural products marketing issues
4. Poor cropping system practices
5. Poor knowledge and adoption of Integrated farming system
6. Improper agricultural financial facilities
7. Rainfall distribution reduced
8. Heat waves causes extreme heat stress in crops

3.6.5 Extension gap

1. Poor awareness about water conservation
2. Poor maintenance of water bodies and water harvesting process
3. Poor awareness about cultivation of less water consuming crops like maize, sorghum and value addition about the crops
4. Poor soil testing and fertilizer management practices
5. Poor awareness and knowledge level about Integrated Pest Management (IPM) practices
6. Poor awareness of crop insurance and weather forecasting
7. Seasonal Migration
8. Poor awareness about judicious use of fertilizers and pesticides

3.6.7 Solutions

1. To address the extension gaps, providing awareness about rain water harvesting and giving education to efficient use of water in agricultural operation through use of drip irrigation, sprinkler irrigation, techniques, adoption of drought resistant varieties of based on the agro ecological condition. Promotion of information, awareness and knowledge about Integrated Pest Management (IPM) and judicious use of fertilizers for sustainable nutrition management to sustain the livelihood of farmers with the integrated farming system practices.
2. The village is getting erratic rainfall over the last ten years, so, promotion of area specific crop-weather forecasting interventions well as weather based crop insurance to reduce the risk of farmers.
3. To narrow down the research gaps, implementation of Geographical Information Systems (GIS) based people

participatory impact oriented climate smart integrated farming systems and farm pond and tank based watershed management practices were suggested to improve the awareness and education level of the farmers and sustainable adoption of various climate smart agricultural practices. The integrated farming systems also promote sustainable food and nutrition security, biodiversity enrichment and other sustainable development goals suggested by the united nations development projects (UNDP).

4. Also, implementation of farm pond based watershed management practices and removal of *Prosopis juliflora*, adoption of drip and fertigation are the appropriate options for better productivity and improvement of the standard of living of the people.
5. It also recommends adoption of drought tolerant cultivars, adoption of less water consuming millets based cropping systems, adoption of semi-arid region specific Integrated Farming System models and utilization of appropriate water use efficiency practices, crops diversification, climate smart agricultural practices of mulching, early sowing, drip and fertigation based micro irrigation practices, reduced tillage and raised bed planting also support to mitigate and improve the sustainable production in the climate impacted farming systems.
6. Policy suggestions: The successful interventions of the climate smart Integrated farming system practices in the semiarid region may be suggested for state level/ regional level policy making process to reduce climate change impacts, natural resources conservation, sustainable livelihoods and farm employment generation initiatives. Other policy suggestions for rain water harvesting, water conservation and soil management through People participatory GIS based management practices by judicious use of fertilizer to reduce the excess use of fertilizer.

4. CONCLUSION

The climate change impacts primarily affect the developing country's agriculture and natural resources which is highly vulnerable due to population pressure. Using Participatory GIS problems to empower them for sustainable

people participatory need based development interventions. The Geographical Information System based people participatory community development research and extension interventions gives holistic development solutions. The information collected through various PRA techniques in the Thattaparai village in *Gudiyatham* block of Vellore district of Tamilnadu in relation to evaluation climate of climate change impacts to design people participatory climate smart agricultural practices oriented climate smart agricultural village supports bring a model climate smart agricultural village in the semi-arid regions of southern India for faster diffusion and adoption of climate smart agricultural models in the south Indian region with the location specific Geographical information system based farming system oriented appropriate climate smart agricultural technologies adoption process. The people participatory climate smart technologies, development process also improves other sustainable development parameters and socio-economic empowerment process in a sustainable manner for making proper institutional policy for larger area adoption of climate smart agriculture to diversify the farm enterprises of small and marginal farmers to double the farmer's income with farming system's specificity.

ACKNOWLEDGEMENTS

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCE

1. IPCC. Summary to Policy Makers. Intergovernmental Panel on Climate Change. 2018;24.
2. Naveen Kumar Arora. Impact of climate change on agriculture production and its sustainable solutions, Environmental Sustainability. 2019;2:95–96.
3. Jemma Gornall, Richard Betts, Eleanor Burke, Robin Clark, Joanne Camp, Kate Willett, and Andrew Wiltshire. Implications of climate change for agricultural productivity in the early twenty-first century, Philos Trans R Soc Lond B Biol Sci. 2010;365(1554):2973–2989.
4. Swaminathan MS, Bhavani RV. Food production & availability-Essential prerequisites for sustainable food security, Indian J Med Res. 2013;138(3):383–391
5. Singh R, Singh GS. Traditional agriculture: A climate-smart approach for sustainable food production. Energ. Ecol. Environ. 2017;**2:**296–316 Available:https://doi.org/10.1007/s40974-017-0074-7
6. FAO. Climate change and food security: risks and responses; 2016. ISBN 978-92-5-108998-9.
7. Rupan, R., Saravanan, R. and Suchiradipta B. Climate Smart Agriculture and Advisory Services: Approaches and Implication for Future. MANAGE Discussion Paper 1, MANAGE Centre for Agricultural Extension Innovations, Reforms and Agripreneurship (CAEIRA), National Institute of Agricultural Extension Management, Hyderabad, India; 2018.
8. Gouranga Kar, Ravinder Singh, Reddy, GP, Kanan K, Verma HN. Participatory rural appraisal technique for research prioritization to improve productivity of rainfed eco system. Resarch Bulletin 9/2002. Water Technology for Eastern Region, Bhubaneswar. 2002;31.
9. Rajula Shanthy T, Monika Singh, Nisha Sahu, Surekha, Balaji Rajkumar M, Gopala Sundara Raj S, Kalyan De, Ramachandran S. Participatory Rural Appraisal: A Holistic Approach for Getting Insight into an Agro-ecosystem Analysis. Indian Res. J. Ext. Edu. 2013;13(2):1-9.
10. Anirban Mukherjee. Prioritization of Problems in Integrated Agriculture: A Case of Rampur Village in Sub Humid Region of Eastern India . Indian Res. J. Ext. Edu. 2015;15(1):53-59.
11. Godert van Lynden, Stephan Mantel. The role of GIS and remote sensing in land degradation assessment and conservation mapping: Some user experiences and expectations. International Journal of Applied Earth Observation and Geoinformation. 2001(1):61-68. DOI:10.1 01 6/S0303-2434(01)85022-4
12. Sabarathnam VE. Manual of Field Experience Training for ARS Scientists, NAARM, Hyderabad; 1988.

13. Mukesh Meena, Pramod Sahu, Alka Joshi and Ibandalin Mawlong, Identification and Prioritization of Problems in Integrated Agriculture for Community Development: A Case of Amba Village in Sub-Humid Region of Western India. Asian Journal of Agricultural Extension, Economics & Sociology. 2018;24(2):1-12.

14. Blesilda M Calub, Participatory Rural Appraisal Guide book. Farming systems and soil resources Institute, College of Agriculture, University of Philippines Los Banos College, Laguna. 2003;4031, Philippines.
Available: www. uplb. edu. Ph