A Study on Problems Faced by the Permaculture Farmers of Paddy Based Agro Forestry System in Sub-Tropical Hill Agro-Climatic Zone of Meghalaya

ABSTRACT

Permaculture, a holistic approach to sustainable agriculture, has gained significant attention worldwide for its potential to address environmental, economic, and social challenges in agriculture. In the context sub-tropical hill agro-climatic zone of Meghalaya, permaculture practices have gained traction, especially in the cultivation of paddy-based agro-forestry systems. Within this backdrop, the adoption of permaculture practices in paddy cultivation has been promoted as a sustainable solution that not only enhances food security but also contributes to ecosystem preservation, soil health improvement, and rural livelihoods. Since the study was taken with the objective of studying problems faced by farmers in the adoption of permaculture practices. This paper focused on appraising the problems faced by the permaculture farmers of paddy based agro forestry system by adopting diagnostic research design with a sample of 60 farmers, covering Sub-Tropical Hill Agro-Climatic Zone of Meghalaya. Major problems and their priorities expressed by the paddy- based agro-forestry farmers in the adoption of permaculture were analysed by using Analytic Hierarchy Process (AHP analysis), it was revealed that unforgiving topography and limited arable land for production and diversification of agroforestry, as the most important problem followed by, Lack of knowledge on permaculture practices such as soil building, water conservation and pest management, Lack of interest in branding and advertisement of the permaculture produce, High initial cost of investment due to transitioning from conventional farming, Permaculture implementation requires change in mentality and level of commitment and lack of supportive and subsidiary policies for permaculture were the major problems under different domains of permaculture. The judgement given by the farmers were found acceptable with inconsistency ratio below 10%. The consensus among seasoned farmers highlights a valuable opportunity to address the permaculture challenges in the region. By pinpointing and prioritizing these bottlenecks, we can effectively target efforts for the successful implementation of permaculture practices in the area.

Keywords: *Permaculture, Agro-forestry system, AHP-analysis, Meghalaya*

1. INTRODUCTION

As India's population and resource consumption continue to rise, there is a growing significance in humans re-establishing a connection with natural systems. Oftentimes, Sustainability can be defined as the practice of using resources in a way that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. That definition creates an illusion of achievability and leaves out the most integral elements of the human

race's ability to sustain itself. Sustainability is value laden and achieving sustainability requires problem solving [1].

Permaculture is a design concept for sustainable, food producing landscapes mimicking the diversity and resilience of natural ecosystems. Although concepts included in permaculture design have been in practice for millenia by various cultures worldwide, the term "permaculture" as it is currently understood was first coined in Tasmania by Bill Mollison and David Holmgren in the mid-1970's [2]. Permaculture is the conscious design and maintenance of agriculturally productive systems which have the diversity, stability and resilience of natural ecosystems. It is the harmonious integration of the landscape with people providing their food, energy, shelter and other material and non-material needs in a sustainable way [3].

The environmental degradation in North Eastern India is attributed to a substantial transfer of soil and nutrients. Estimates suggest that approximately 601 million metric tons (MT) of soil and the following quantities of nutrients have been transferred: 685.8 MT of nitrogen (N), 99.8 MT of phosphorus (P), 511.1 MT of potassium (K), 22.6 MT of manganese (Mn), 14.0 MT of zinc (Zn), 57.1 MT of calcium (Ca), and 43.0 MT of magnesium (Mg) [4]. The North-Eastern region of India has experienced notable changes in the pattern of major climatic variables such as rainfall and temperature. Average temperatures are projected to increase in almost all the districts of the region while annual rainfall is also reported to increase in almost 3/4th of the districts [5]. Permaculture is an approach that could contribute to the sustainability of social and ecological systems (6]. It aims to improve food security, help farmers adapt to climate change and assist to climate change mitigation by adopting appropriate practices, developing enabling dogmas and institutions and mobilizing needed finances.

Paddy based agroforestry is a dynamic and ecological based natural resource management system. It integrates paddy with vegetables, timber and non-timber forest products in farm and rangelands, diversifies and sustains production for increased social, economic and environmental benefits [7]. Keeping into purview the exigency to restore the complex, diverse and risk prone conventional agricultural systems of the hill state of Meghalaya, the problems faced by the permaculture farmers of paddy based agro forestry system were studied under the study.

2. MATERIALS AND METHODS

2.1 Research Design:

Diagnostic research design was adopted for the study. A diagnostic research design is a specific type of research design used to investigate and understand the causes, nature or characteristics of a particular phenomenon, problem or condition. The primary goal of diagnostic research is to gather information and evidence that can be used to determine the presence or absence of a particular condition, assess its severity, or identify contributing problems. In this

research it focuses on answering questions such as "What is the problem?" or "What is causing the problem?" of permaculture rather than evaluating the effectiveness of interventions or treatments [8].

2.2 Site Description

Meghalaya is located within the Eastern Himalaya zone – II, which is further sub-divided into five sub regions, taking into consideration of topography, rainfall, temperature, soil type and cropping system. For the purpose of planning for development, research and extension, the state has been divided into three Agro-Climatic Zones (ACZs). They are namely Tropical zone (100 – 300mMSL), Sub-tropical zone (300-1100mMSL) and Temperate zone (1100-2000m MSL) [9]. Description of ACZs of Ri-Bhoi district 10] is mentioned in the following Table 1.

Table 1: Agro-Climatic Zones of Ri-Bhoi district of Meghalaya.

S. No.	Agro-climatic Zone	Characteristics
1	Subtropical hill zone	400-1200m MSL, Temperature: 32ºC-12ºC, All area of Ri-Bhoi district except southern part
2	Mild tropical hill zone	200-800m MSL, Temperature: 30 - 12ºC, Southern part of Ri-Bhoi district

2.3 Sampling Procedure

2.3.1. Selection agro climatic zone

Sub-tropical hill agro climatic zone of Meghalaya was selected purposively based on the criteria of paddy is grown largely in the sub-tropical hill ACZ of the state Meghalaya. The research project DHaBReT has intervened in this particular ACZ on the crop paddy.

2.3.2. Selection of villages

Three (3) villages, namely (i) Thadnongiaw (ii) Liarkhla iii) Kudungulu which are in the Sub-Tropical Hill ACZs of Meghalaya at Bhoirymbong C&RD Block, Ri-Bhoi district under the with IIDS in Providing Evidence Based Agro-Advisory Services to Farmers of North-East India" *a.k.a* DHaBReT selected purposively.

2.3.3. Selection of respondents

A total of 60 farmers were selected purposively based on the criteria of farmers having agro-forestry lands and have a consolidated area of not less than 01 ha.

3. Tools and techniques

In the present study, Analytic Hierarchy Process (AHP) Analysis of permaculture problems has been undertaken in a three-step process. In the first step, possible problems relating to the

permaculture are identified. In the second step, pair-wise comparisons of problems in different domains of permaculture are made. Pair-wise comparisons were conducted separately for all problems within a category and a priority value for each problem is computed using the Eigen value method. The problems with the highest priority value under each permaculture category are brought forward for comparison with the highest priority value problems from other categories.

In the third step, participants make pair-wise comparisons of the problems that are brought forward and a scaling problem or global priority value for each category is computed. Scaling problems and priority values are used to calculate the overall or global priority of each problem shown below:

Overall priority of $problems_{ij}$ = (Priority value of $problem_{ij}$) *(scaling problems of permaculture category)

Where, i = number of problems in a permaculture category, and j= 6 (Situational, Production, Marketing, Financial, Personal, Institutional and social problems)

The overall priority scores of problems under categories indicates the relative importance of each problem.

The matrix of pair-wise comparisons (Eq. 1) is constructed in Step 2. In this matrix, the element $a_{ij} = 1/a_{ji}$ and thus, when $i = j$, $a_{ij} = 1$. The value of w_i may vary from 1 to 9 and 1/1 indicates equal importance while 9/1 indicates extreme or absolute importance.

$$A = (a_{ij}) = \begin{bmatrix} 1 & w_1/w_2 & \dots\dots & w_1/w_n \\ w_2/w_1 & 1 & \dots\dots & w_2/w_n \\ w_n/w_1 & w_n/w_2 & \dots\dots & 1 \end{bmatrix} \quad (1)$$

In the comparisons, some inconsistencies can be expected and accepted. When 'A' contains inconsistencies, the estimated priorities can be obtained by using the matrix (Eq. 1) as the input using the Eigence value technique (Eq. 2).

$$(A - \lambda_{maxn} I)\, q = 0 \quad (2)$$

Where, λ_{max} is the largest Eigen factor of matrix A; q is its correct Eigen factor; and I is the identity matrix. The correct Eigen factor, q, constitutes the estimation of relative priorities. It is the first principal component of the matrix of pair-wise comparisons. If the matrix does not include any inconsistencies, i.e. the judgments made by a decision maker have been consistent, q is the exact estimate of the priority vector. Each Eigen factor is scaled to sum up to one to obtain the priorities. Saaty [11] has shown that λ_{max} of a reciprocal matrix A is always greater or equal to n (=number of rows = number of columns). If the pair-wise comparisons do not include any inconsistencies, λ_{max} = n. The more consistent the comparisons are, the closer the value of computed λ_{max} is to n. Based on this property, a consistency index, CI, has been constructed (Eq.

3).

$$CI = (\lambda_{max} - n)\,(n - 1) \qquad (3)$$

The CI estimates the level of consistency with respect to a comparison matrix. Then, because CI is dependent on *n*, a consistency ratio CR is calculated, which is independent of (Eq. 4). Itmeasures the coherence of the pair-wise comparisons. To estimate CR, the average consistency index of randomly generated comparisons, ACI, has to be calculated. ACI varies functionally, according to the size of the matrix [12].

$$CR = 100\,(CI/ACI) \qquad (4)$$

As a rule of thumb, a CR value of 10% or less is considered to be acceptable. Otherwise, all or some of the comparisons must be repeated in order to resolve the inconsistencies of the pair- wise comparisons. Thus, the results of the comparisons are quantitative values expressing the priorities ofthe problems included in permaculture problem analysis.

To complement and intensify the research in the present study, the AHP was executed in estimating the relative priorities for each factor and domain. The relative priorities of problems and domains are estimated using the Eigen value technique [13, 14]. The Permaculture problems-AHP analysis conceded the following steps.

Table 2. Pair-wise comparison scale on AHP predilections

Anchored Rating	Judgement of preferences
1	Equally Preferred
2	Equally to Moderately Preferred
3	Moderately Preferred
4	Moderately to Strongly Preferred
5	Strongly Preferred
6	Strongly to Very StronglyPreferred
7	Very Strongly Preferred
8	Very Strongly to ExtremelyPreferred
9	Extremely Preferred

In order to reflect the relative importance amongst problems of each domain, the farmers were requested to perform pair-wise comparisons of the putative problems in each domain by using the Graphic Anchored Rating Scale – 'Pair-Wise Comparison Scale for AHP Preferences' with a rating of '1 – 9' as expounded in Table 2.

3.1 Pair-wise comparison between problems of different domains of permaculture by implying AHP: The problem with the highest local priority has beenchosen from each domain to represent the domain. The identified problems weresubjected to perform pair-wise comparisons by following the same Graphic Anchored Rating Scale as mentioned in previous para. The scores obtained were the scaling problems of the six permaculture groups and they were used to calculate

the overall, that is, global priorities of the independent within them.

4. RESULTS AND DISCUSSION

A thorough examination of Table 3 and Fig. 1 could unveiled that the farmers expressed their agreement on ranking the permaculture problems S1 - Unforgiving topography and limited arable land for production and diversification of agrofrestry as most important factor followed by the problems, namely S2- Soil erosion and nutrient loss due to heavy rainfall, wind and improper land management practices, S3 - Climate Variability such as temperature fluctuations, unpredictable rainfall patterns and increased incidence of extreme weather events like storms, hail and landslides and S4 - Difficulty in water management due to the uneven terrain and variable precipitation patterns under the domain of situational problems with identified problems faced by the farmers in the study with the local priority scores of 0.482, 0.295, 0.129 and 0.091 respectively. On one hand, it could be inferred that the relative importance of S1 amongst the four identified problems under the domain of Strength was nearly forty eight percent (48.34%). The inconsistency ratio was found to be 0.025 which is below the acceptable limit of 0.10. The inconsistency ratio indicates a measure of how logical or rational the decision is. An inconsistency ratio of 0.10 or less is generally considered acceptable and a larger inconsistency ratio value indicates more inconsistent judgement which needs to be re-examined for making decision.

Table 3. List of agreed upon permaculture problems, local and global priority scores and respective inconsistency ratios* on pair-wise comparison amongst problems # of each domain and between problems of domains of permaculture by implying AHP

Permacultue domain & their problems		Local priority scores of problems	Inconsistency Ratio	Global priority scores
A.	**Situational problems**			**0.367**
S1	Unforgiving topography and limited arable land for production and diversification of agrofrestry	**0.482**	0.025	0.178
S2	Soil erosion and nutrient loss due heavy rainfall, wind and improper land management practices	0.295		0.109
S3	Climate Variability such as temperature fluctuations, unpredictable rainfall patterns	0.129		0.047
S4	Difficulty in water management due to the uneven terrain and variable precipitation patterns	0.091		0.033
B.	**Production problems**			**0.473**
P1	Lack of knowledge on permaculture practices such as soil building, water conservation and pest management	**0.330**	0.024	0.074
P2	Lack of availability of indigenous quality planting material/species suitable to agro climatic zone.	0.233		0.052
P3	Lack of availability of inputs such as organic matter, compost, mulching materials, water harvesting	0.152		0.034

	structures and natural pest control mechanisms			
P4	Infestation of disease and pest due to inefficiency of preventive measures and biological control methods	0.104		0.023
P5	Declining yield due to factors such as pest and disease pressure, limited nutrient availability, soil health issues, Soil erosion and nutrient loss due heavy rainfall, wind and improper land management practices	0.071		0.016
P6	Its demands of significant amount of time and effort due to its tasks such as planning, design and implementation.	0.048		0.124
P7	Prevalent labor shortage due to harsh terrain and difficult working conditions and migration.	0.034		0.087
P8	Inadequate/Lack of availability of mechanical inputs/tools like such as hand tools composting systems, power tillers, brush cutters, or chainsaws	0.024		0.063
C.	**Marketing problems**			**0.156**
M1	Lacks standardized certification systems which assurance to consumers about the authenticity and sustainability of products	0.118		0.028
M2	Lack of specialized market connectivity for permaculture produce	0.262	0.030	0.041
M3	Inadequate information on the markets and price of produce	0.178		0.052
M4	Lack of interest in branding and advertisement of the permaculture produce	**0.330**		0.018
M5	Lack of trading experience of e-marketing platforms	0.06		0.010
M6	Lack of storage facilities	0.045		0.007
D.	**Financial problems**			**0.044**
F1	High initial cost of investment due to transitioning from conventional farming	**0.539**	0.070	0.024
F2	Permaculture implementation result in short-term losses during the initial stage	0.297		0.013
F3	High cost of permaculture inputs such as bio-pesticides, construction mechanisms etc	0.163		0.007
E.	**Personal problems**			0.030
Pc 1	Permaculture implementation requires change in mentality and level of commitment	**0.437**	0.061	0.016
Pc 2	Permaculture practices are difficult to understand and implementation requires a shift in knowledge and skills.	0.299		0.009
Pc 3	Drudgery problems due to nature of farming tasks, working conditions and lack of appropriate tools or technologies.	0.263		0.005
F.	**Institutional and social problems**			**0.069**
I1	Lack of supportive and subsidiary policies for permaculture	**0.460**	0.029	0.046
I2	Lacking the support of capacity building programmes on permaculture branding	0.302		0.030

I3	Lack of coordination for formation of SHGs on permaculture production	0.142		0.014
I4	Negativism of community in permaculture production	0.094		0.009

*The inconsistency ratio of the pair comparison between the domains of permaculture problems was 0.030.
The greatest weight with respect to each domain of problems of permaculture was underlined.

Referring the same Table 3 and Fig. 1 it could be narrated that the farmers expressed their agreement on ranking the problems of permacuture P1 - Unforgiving topography and limited arable land for production and diversification of agrofrestry as most important factor followed by the problems, namely P2- Lack of availability of indigenous quality planting material/species suitable to agro climatic zone, P3 - Lack of availability of inputs such as organic matter, compost, mulching materials, water harvesting structures and natural pest control mechanisms, P4- Infestation of disease and pest due to inefficiency of preventive measures and biological control methods, P5- Declining yield due to problems such as pest and disease pressure, limited nutrient availability, soil health issues, Soil erosion and nutrient loss due heavy rainfall, wind and improper land management practices, P6- Its demands of significant amount of time and effort due to its tasks such as planning, design and implementation, P7- Prevalent labor shortage due to harsh terrain and difficult working conditions and migration and P8 - Inadequate/Lack of availability of mechanical inputs/tools like such as hand tools composting systems, power tillers, brush cutters, or chainsaws under the domain of production problems with identified problems faced by the farmers in the study with the local priority scores of 0.330, 0.233, 0.152, 0.104, 0.07, 0.549, 0.386 and 0.279respectively. On one hand, it could be inferred that the relative importance of P1 amongst the eight identified problems under the domain of production was nearly Thirty three percent (33.00%). The inconsistency ratio was found to be 0.024 which is below the acceptable limit of 0.10. [15, 16]

Similarly, in case of problems under the domain-Marketing, by referring Table 2 and Fig.1 it could be reflected that the farmers expressed their agreement on ranking the problems M4 – Lack of interest in branding and advertisement of the permaculture produce, as most important factor followed by the problems, namely M2- Lack of specialized market connectivity for permaculture produce, M3- Inadequate information on the markets and price of produce, M1- lacks standardized certification systems which assurance to consumers about the authenticity and sustainability of products, M5- Lack of trading experience of e-marketing platforms and M 6- Lack of storage facilities under the domain of marketing problems with identified problems faced by the farmers in the study with the local priority scores of 0.118, 0.262, 0.178, 0.330, 0.06, and 0.045 respectively.. On one hand, it could be inferred that the relative importance of M4- amongst the six identified problems under the domain of Marketing problems was nearly forty four percent (33.00%). The inconsistency ratio was found to be 0.030 which is below the acceptable limit of 0.10 indicating a very well reliable judgement amongst the farmers. [17].

Pertaining the table Table 3 and Fig.1 could unveiled that the farmers expressed their agreement on ranking the permaculture problems PC1 - High initial cost of investment due to transitioning from conventional farming as most important factor followed by the problems, namely PC2- Permaculture practices are difficult to understand and implementation requires a shift in knowledge and skills and PC3 - Drudgery problems due to nature of farming tasks, working conditions and lack of appropriate tools or technologies under the domain of personal problems with identified problems faced by the farmers in the study with the local priority scores of 0.437, 0.299 and 0.263 respectively. On one hand, it could be inferred that the relative importance of Pc1 amongst the three identified problems under the domain of personal problems was nearly forty forty three percent (43.00%). The inconsistency ratio was found to be 0.061 which is below the acceptable limit of 0.10 indicating a very well reliable judgement amongst the farmers [18].

Revealing from the Table 3 and Fig. 1 could unveiled that the farmers expressed their agreement on ranking the permaculture problems F1- High initial cost of investment due to transitioning from conventional farming as most important problem followed by the problems, namely F2- Permaculture implementation result in short-term losses during the initial stage and F3- High cost of permaculture inputs such as bio-pesticides, construction mechanisms etc., under the domain of financial problems with identified problems faced by the farmers in the study with the local priority scores of 0.539, 0.297 and 0.163 respectively. On one hand, it could be inferred that the relative importance of Pc1 amongst the three identified problems under the domain of personal problems was nearly forty fifty three percent (53.00%). The inconsistency ratio was found to be 0.070 which is below the acceptable limit of 0.10 indicating a very well reliable judgement amongst the farmers. [19].

When the problems under the domain- Institutional and social problems are studied by refereeing data from Table 3 and by reflecting the Bar graph of Fig. 1, it could be narrated that the farmers expressed their agreement on ranking the problems I1- Lack of supportive and subsidiary policies for permaculture' as most important problem followed by the, namely I2 Lacking the support of capacity building programmes on permaculture branding, I3 - Lack of coordination for formation of SHGs on permaculture production and I4- Negativism of community in permaculture production under the domain of institutional and social problems with identified problems faced by the farmers in the study with the local priority scores of 0.460, 0.302, 0.142 and 0.094 respectively. On one hand, it could be inferred that the relative importance of I1 amongst the four identified problems under the domain of institutional and social problems was nearly forty fifty three percent (46.00%). The inconsistency ratio was found to be 0.029 which is below the acceptable limit of 0.10 indicating a very well reliable judgement amongst the farmers. [20, 21].

Global priority scores between problems of different domains of Permaculture

Apropos of global priority scores between different domains of problems of permculture, referring Table 3, it could be perceived that the scaling factor score for the domain production problems was 0.473, which remain to be the highest when examined against the remaining three domains viz., Situational problems, Marketing problems, Institutional and social problems, financial and personal having scaling factor score of 0.367, 0.156. 0.069. 0.044 and 0.030 respectively.

Subsequently inferring the same Table 3 and Fig. 2, it could be observed that the permaculture farmers expressed their agreement upon ranking the problems from highest to lowest under the domain of situational problems as S1, S2, S3 and S4 with the global priority scores of 0.178, 0.109, 0.047 and 0.033 respectively. Similarly, Under the domain of production problems, the global priority scores for the problems from highest to lowest were in the trend of P1, P2, P3, P4, P5, P6, P7 and P8 with the respective scores of 0.074, 0.052, 0.034, 0.023, 0.016, 0.124, 0.087 and 0.063. Focusing toward the problems under the domain of Marketing, the global priority scores from highest to the lowest were in the inclination of M4, M2, M3, M1, M5 and M6 with the respective scores of 0.052, 0.04, 0.028, 0.018, 0.010 and 0.007. Considering the problems under the domain of financial problems, the problem F1 possessed the highest global priority score followed by F2 and F4 with the corresponding scores of 0.024, 0.013 and0.007. Revealing the problems under the domain of personal problems, the problem Pc1 possessed the highest global priority score followed by Pc2 and Pc3 with the corresponding scores of 0.016, 0.009 and 0.005. Observing the problems under the domain of Institutional and social problems, the problem I1 possessed the highest global priority score followed by I2, I3 and I4 with the corresponding scores of 0.046, 0.030, 0.014 and 0.009. The overall inconsistency ratio was found to be 0.08 which is below the acceptable limit of 0.30 reflecting a considerable reliable judgement amongst the farmers.

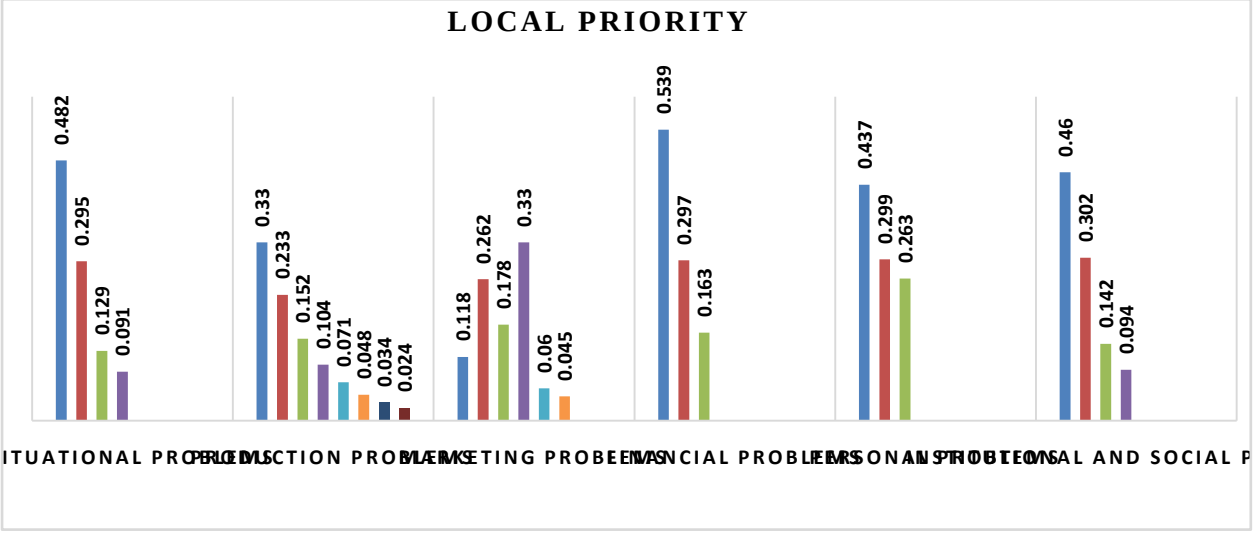

Fig. 1. Permaculture problem analysis for Local priorities

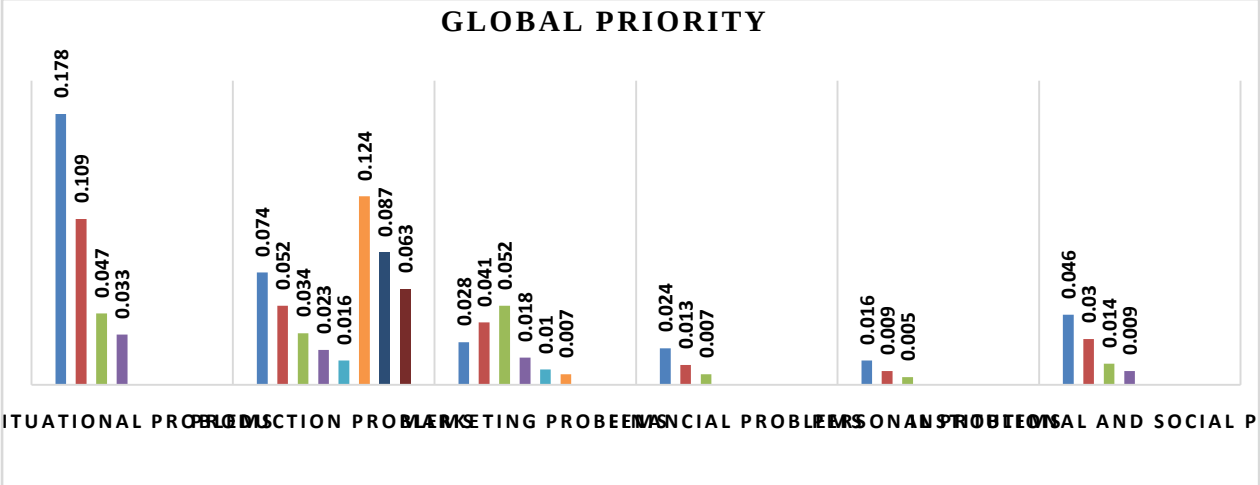

Fig. 2. Permaculture problem analysis for Global priorities

1. CONCLUSION

Sustainability of agriculture becoming challenge to mankind. Permaculture practices are the alternate option to make agriculture sustainable dealing with conventional agriculture and climate variation. For this one need to identify and prioritize the possible and important problems of permaculture. The study could make out analysis of problems under the six domains *viz.*, Situational, Production, Marketing, Financial, Personal and Social and Institutional problems of permaculture. Problems identified under each domain were also found having overall inconsistency ratio below the acceptable limit of 0.10 reflecting reliable judgement amongst the farmers showing a helpful scope for focusing the problems of permaculture that are facing in the region and need to be tackle for successful adoption of practices in the region. Similar research study needs to be carried out in large scale to spot the areas that need to give more importance for better farming and to bring sustainable development in the region.

References:

1 Tainter, J. (2003). A frame work for sustainability. *World Futures*, 59(3-4), 213-223.

2 Krebs, J. and Bach, S. (2018). Permaculture scientific evidence of principles for the agroecological design of farming systems. *Sustain.*, 10(9): 3218.

3 Bell, G. (2004). The permaculture way: Practical steps to create a self-sustaining world. Hampshire, United Kingdom: Permanent Publications.

4 Saha, R., Chaudhary, R.S., and Somasundaram, J. (2012). Soil health management under hill agroecosystem of North East India. *Appl. Environ. Soil. Sci.*, 12: 1288-1294.

5 Roy, D. Kolady, B. Paudel, A. Yumnam, N. Mridha, D. and N.U. Singh. (2021). Recent trends and impacts of climate change in North East India- A Review. http://doi.org/10.22438/jeb/42/6/MRN-1701.

6 Gomiero, T., Pimentel, D., and Paoletti, M.G. (2011). Is there a need for a more sustainable agriculture? *Crit. Rev. Plant. Sci.*, 30: 6–23.

7 7. Leakey, R.B. (1996). Definition of agroforestry revised. Agrofor. Syst., 8(1):5-7.

8 Kerlinger, F.N. (1996). Foundations of behavioral research. Holt, Rinehart and Winston: New York.

9 Megagriprofile. (2008). Meghalaya agriculture profile. http://megagriculture.gov.in/public/MegAgriProfile2006.pdf. Accessed 12 February 2022.

10 KVK. (2022). Description of agro-climatic zones of Ri-Bhoi district. http://kvkribhoi.nic.in/agro-climatic-zone.html. Accessed 12 February 2022.

11 Saaty TL. A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology*. 1977;15(3): 234–281.

12 Saaty TL. The analytic hierarchy process. McGraw- Hill, New York; 1980.

13 Schmoldt DL, Peterson DL. Efficient group decision making in workshop settings. In Schmoldt DL, Kangas J, Mendoza GA and Pesonen M (Eds.), The analytic hierarchy process in natural resource and environmental decision making. Dordrecht, The Netherlands: Kluwer Academic Publishers. 2001;97–114.

14 Ananda J, Herath G. The use of analytic hierarchy process to incorporate stakeholder preferences into regional forest planning. *Forest Policy and Economics*. 2003; 5:13–26.

15 Zahra, D. and James, G. (2019). Permaculture: Challenges ad benefit improving rural livelihood in South -Africa and Ziomawe. *Sustain.*, 11(8): 2219.

16 Didarali, Z. and Gambiza, J. (2019) Permaculture: Challenges and Benefits in improving rural livelihoods in South Africa and Zimbabwe. *Sustainability*, doi:10.3390/su11082219.

17 Mercer, T. (2016). Permaculture: Barriers Preventing Farmers from Integrating Sustainable Techniques and Solutions to Help Overcome Them. Program on the Environment, University of Washington.

18 Jonkoping University. (2019). Minor field studies (MFS). https://ju.se/student/exchange/scholarships/minor-field-studies-mfs.html. Accessed 12 October, 2021.

19 Vats, R. (2021). The Main Challenges of Permaculture. https://theagrotechdaily.com/main-challenges-permaculture. Accessed 3 January, 2023

20 Futurside (2022). Benefits of Permaculture and Challenges you need to know. https://futurside.com/permaculture-benefits-and-challenges-you-need-toknow/#Difficult_to_scale_up. Accessed on 3 January, 2022.

21 Calderon, C.I., Jeronimo, C., Praun, A., Reyna, J., Castillo, I.D.S., Leon, R., Hogan, R., and Cordova, J.P.P. (2018). Agroecology-based farming provides grounds for more resilient livelihoods among smallholders in Western Guatemala. Agroecol. *Sustain. Food Syst.*, 42(10): 1128-1169.