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AN ANALYTICAL REVIEW OF CROPPING SYSTEM RESEARCH IN INDIA- A CASE STUDY

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Abstract

The future agriculture will be guided by the compulsions of food and nutritional security, by the concerns of environmental protection, and profitability of farm enterprises. Cropping system research could be highly effective in providing balanced food and regular employment, sustaining soil health, and increasing farm productivity and farm income which would ultimately increase the purchasing power of farmers. Andhra Pradesh was one among the typical cases representing South East Asian conditions registering prominent and favourable shifts in the form of relatively diversified cropping patterns. Study of the dynamics, determinants of cropping systems and their implications is of paramount importance for planning the future agricultural policies. Results of the study indicated that paddy continues to be the most beneficial crop due to its agronomic suitability; economic viability as it is the staple food crop of the region. Similarly implications out of Analyses of rain fed cropping systems, Horticulture and vegetables based cropping system, and Energy utilization of major cropping systems etc. were also discussed and conclusions were drawn to develop the suitable strategies for the sustainable agriculture development in this region.

Key words: *Cropping systems, Environmental protection, Nutritional security*

INTRODUCTION

Cropping system research is an inter disciplinary approach which should be highly effective in providing balanced food and regular employment, in sustaining soil health, in integrating aberrant weather situation and in increasing farm productivity and farm income which would ultimately increase the purchasing power of farmers [37]. The objectives of the cropping systems development are the effective utilization of all the natural resources which includes the land, water and solar radiation in order to achieve the higher production and high net returns in a sustainable manner [11]. The yield factor i.e., quantity of produce obtained per unit resources in a unit time is the standard parameter in achieving the above objective. Cropping systems research is also advantageous for maintaining soil health so as to achieve the land productivity and improved physical properties of soil and reduced risk of soil degradation [14]. Spatial and temporal analysis of cropping pattern changes both at an all India and states level for 50 years revealed that the economic and non-price factors influence the cropping pattern changes at macro and micro level [25]. Downward trends observed in the employment opportunities in the field of Agriculture sector and disequilibrium in crop and varietal selections have weakened the existing traditional, conventional and inter sectorial linkages between Agricultural, horticultural crops and livestock sector [4]. The cropping pattern changes so resulted would have complications in future agricultural research, skill orientation of personnel engaged in agriculture, conservation of nature, institutional arrangement, agro processing and expansion of non-farm sectors.

Agriculture is an important sector in the economy of the state of Andhra Pradesh in India. It is the biggest source of employment provider. Out of 34.89 million employees in the state (according to 2011 census) agriculture and allied sector provide employment to 21.69 million workers (62.14%) besides its contribution to the net domestic product [3]. Considerable change has occurred in the structure of agriculture in

Andhra Pradesh. The cropping pattern has shifted towards paddy and sugar cane among irrigated crops and cotton and groundnut among dry crops. The net sown area under millets is also reduced drastically [6]. Hence prominent and favourable shifts have taken place in the state of Andhra Pradesh in the form of diversified cropping systems. Study of the dynamics, factors affecting cropping systems and their implications is of paramount importance for planning the future agricultural policies. However, spatial and temporal analysis of the dynamics, determinants and its implication is difficult through conventional investigative research planned for fixed period of time [8]. Hence, an analytical review of the cropping system research was attempted with the following objectives:

(i) To analyse the economic aspects of various existing cropping systems in the state of Andhra Pradesh.

(ii) To study the determinants and factors affecting the existing cropping systems in the state of Andhra Pradesh.

(iii) To analyse the existing cropping systems in the state of Andhra Pradesh both in temporal and spatial dimensions.

MATERIALS AND METHODS

Methodologies those were adopted while reviewing the cropping system research were as fallows.

1. Costs and returns analysis
2. Benefit cost ratio
3. Energy utilization
4. Sustainability index
5. Resource use efficiency and inefficiency
6. Linear programming
7. Returns to scale

The methodologies that were not found in cropping system research of Andhra Pradesh but were still found in the research literature of cropping systems elsewhere are detailed hereunder:

•Budgeting techniques

•Participatory research for a period to know the sustainability of the cropping system.

•Decision supporting systems for cropping system analysis.

•Total factor productivity.

•Extensions of linear programming.

•Seven factor additive model.

•Ranking techniques, shadow pricing and opportunity costing.

•Production and productivity to observe the economic superiority the cropping systems.

Cropping system research in Andhra Pradesh

A review was attempted to study the major cropping systems prevailing in the state of Andhra Pradesh for their economic viability resource use efficiency and environmental sustainability, factor productivity and finally for optimal crop planning as it was done in the state of Gujarat [15]. Spatial analysis of various cropping systems was studied to know the suitability of cropping systems in various agro, climatic zones of Andhra Pradesh. Temporal analysis was done to know the dynamics of various factors affecting the cropping systems and in turn the agriculture of Andhra Pradesh.

RESULTS AND DISCUSSIONS

Paddy based cropping systems

Paddy is the important food crop in Andhra Pradesh. Paddy-Paddy is the most beneficial cropping system among cropping systems studied in Guntur district such as Paddy-Paddy, Dry paddy – Ground nut, Paddy – Blackgram– Cucumber, Dry Paddy – Red gram, Groundnut-Red gram, Bajra-Red gram, Ground + Red gram and Bajra + Red gram [36]. Studies conducted for the period 1965-2000 in Assam revealed the changes in cropping pattern in favour of food crops and the greater contribution of the food crops was due to expansion effect [23]. Among the cropping systems Rice-Rice – HYV Rice, Rice-rice-wheat and Rice-HYV rice, rice-fallow-HYV ice, rice-chilli-fallow and rice-jute-potato studied in Bangladesh during 2000-01, rice-rice-HYV rice was found to be the beneficial cropping system [31]. The superiority of the rice when compared to wheat, jute and the importance of HYV in cropping systems was established by this study [1]. These findings are important in command areas of the Indian sub continent

where paddy based intensive agriculture is practiced.

Studies conducted during 1984-85 in Krishna district for comparison of rice-rice and rice-pulse cropping systems [29] resulted in both the systems being statistically on par in yields whereas economic analysis of Paddy based cropping systems in Nellore district [43] revealed the superiority of paddy-pulse rotation over monoculture. The ill effects of monoculture of paddy in the traditional belts might be more evident by 1995 when compared to 1985 in Andhra Pradesh.

Paddy and redgram were the beneficial crops among paddy, chillies, cotton and Redgram in Prakasam district [16].

Sugarcane based cropping systems

Sugarcane, paddy two-year rotation was found to be the most common cropping pattern observed in Andhra Pradesh [5]. Economic analysis of sugarcane based cropping systems was not found in Andhra Pradesh. Hence works done in U.P during 1999-2001 [40] regarding various intercrops such as potato, mustard, Green gram, Blackgram chickpeas and wheat raised along with sugarcane and their profitability revealed that the yield of sugarcane was even higher with potato and chickpea as intercrops compared to sugarcane alone.

Cotton based cropping systems

While analysing the comparative economics of cotton against soybean based cropping systems viz. Soybean - bengal gram, soybean + redgram and soybean-jowar, and found that all the soybean based cropping systems were economically beneficial and sustainable when compared to cotton crop [30].

Similar results were obtained in Maharastra during 1996-97 [20] where soybean was found to be beneficial than the cotton, sorghum and soybean that were analysed for the economics.

Analysis of rain fed farming systems

Agriculture in Andhra Pradesh like other states of India is predominantly rain fed in nature. Economic analysis of cropping systems in rain fed conditions and consequent identification of beneficial crops and cropping systems under this condition would be beneficial for majority of farmers who cultivate crops under rain fed conditions. Rain fed conditions involves resource scarce, constrained conditions and risk. Hence, identification of beneficial cropping systems under rain fed conditions involves application of complicated economic tools, which could estimate risk and optimal use of scarce resources under constrained conditions [39]. It was also concluded as the same [19] and reported that crop and varietal diversification of rain fed rice based cropping systems for higher productivity and profitability in Eastern India.

Groundnut and millets are the crops that predominately occupy the rain fed areas in Andhra Pradesh. Efforts were made to review the economic analysis that was attempted in these crops in Andhra Pradesh and also comparable literature elsewhere in India and other entries. It was also revealed [42] that groundnut intercropped with pigeon pea recorded significant increase in pod yield. It also registered higher net returns in both good and bad years in red sandy loams of Tirupathi, when compared to groundnut monocarp grown with one row skipping. Virtual academy of semiarid tropics of ICRISAT, Hyderabad revealed that sorghum – groundnut two years rotation, chickpea (residual moisture double cropping) were beneficial. Analysis of millet based cropping systems analysed in middle Gujarat during 2011-12 concluded that the hybrid napier + cowpea + lucern higher than maize-potato – bajra, Bajra-cowpea-lucerne, sorghum-potato-bajra, bajra-lucerne, bajra-potato-bajra+cowpea and hybrid napier + cowpea + lucerne, whereas bajra-potato-bajra+cowpea had got highest gross and net returns. Pearl millet + potato+tomato system highest under irrigated conditions in a semi-arid environment among the pearl millet monocrop, potato-potato, pearl millet-potato-green gram, cotton-wheat and soybean-wheat-fodder cowpea.

Analysis of rain fed farming system through linear programming technique in Chattisgarh during 1998-99 revealed that in farms with on-farm irrigation nearly 15 percent of crop area was allocated to vegetables in all the three crop seasons which contributed to 50.69 percent to the gross income under on-farm

irrigation [21]. Similar studies also [8] indicated that mono-cropping is the most common farming practice followed in the North Eastern Hilly Region (NEHR) of India and farmers leave the land fallow after harvesting the main crop.

The identification of suitable sequential crops is essential to increase the cropping intensity, land-use efficiency and overall productivity of the land. A study was carried out during 2008–09, 2009–10 and 2010–11 on maize (rainy season) followed by table pea, mustard, French bean and groundnut (post rainy season) [7]. Sequence crops were imposed with paddy straw mulch at 5.0 t ha−1 and without mulch. The availability of water and moisture retention was higher ($p < 0.05$) on mulched plots, yield was also higher. However, recorded soil temperature was higher on mulched plots at 08.00 hours and lower at 12.00 and 16.00 hours compared with the no-mulch plots. Recorded maize equivalent yield, production efficiency, economics and total energy use and output (MJ ha−1) were higher for maize–French bean.

Horticulture and vegetables in cropping system

Research on coconut based high density cropping system in the farm of intercropping banana cv grand-nain-wilhams, pineapple cv, Grandkew and black pepper cv karimunda with coconut cv Bernaulim resulted in higher total number of nuts than the mono cropped coconuts in Goa during 2000-01 [41]. Intercropping of banana, pineapple vanilla suitable to the east west areas in Konaseema (East Godavari dist.) uddanam (Srikakulam) and other traditional coconut growing areas in Andhra Pradesh might brought additional returns to the farmers and other benefits. Location specific research on other crops suitable for intercropping with coconut might bring still encouraging results.

Pulses and vegetables were found to be beneficial crops among the crops that were economically analysed in Jharkhand [18] through linear programming techniques. Cauliflower, cabbage, tomato, radish, bean and bottle ground were the beneficial crops among the winter vegetables that were studied during 1997-98 in Bangladesh [2]. Tomato intercropped with cotton yielded higher returns in Pakisthan when compared to the tomato, cotton mono crops grown separately. A case study conducted in Himachal Pradesh between 1940-90 revealed that the agriculture had shifted from the cultivation of staple crops, grain legumes, tuber crops and oil seed crops to vegetables and fruits. Potato intercropped with garlic 2:1 ratio in Uttaranchal found when compared to potato, garlic pure crops and potato intercropped with 1:1 ratio [40].

Cropping system in command areas

The economic evaluation of cropping system in the command areas involves collection of input-output data in three reaches of the canal. Certain studies [33] also concluded the following facts about the cropping system research conducted left bank canal command of Tungabhadra project. The results would have implications for the command areas of Andhra Pradesh also. Kharif crops, in general and rice, in particular dominate the cropping system in the command area. Diversified cropping systems were noticed in the tail reach. In the head reach, rice-rice system was not only widespread but also profitable. In the middle reach, cotton was the most profitable and widespread system. Rice-rice, cotton, groundnut-groundnut, fallow-jowar and sunflower-jowar cropping systems were popular in the tail reach [32]. However, the rice-rice system was more profitable, in Toto. It was also reported that [15] the Rice (Oryza sativa L.) and maize (Zey mays) are grown in 3.5 million hectares (Mha) in Asia that includes 1.5 Mha in South Asia. Sequentially these crops are grown on the same land in the same year either in double–or triple-crop systems for the increasing demand of rice for the escalating human population and maize for the livestock and poultry. A critical analysis of the available literature on agro-ecosystems and adaptations, its territorial spread of the technologies, yield potential and yield gaps, and fertilizer management schedules adopted for rice-maize (R-M) systems in in India and South Asia outlines principles of Integrated nutrient management for R-M systems, and identifies development,

refinement, and dissemination of the integrated plant nutrition system technologies based on location-specific, microclimate oriented fertilizer management principles as priorities for future research to increase the productivity, profitability, and sustainability of Rice –Maize cropping systems.

Energy utilization of major cropping systems

Study of inputs as energy sources for crops and cropping systems would be useful to know the economic and environmental sustainability of cropping system. A cropping system, which uses chemical fertilizers and pesticides more, is less sustainable economically and environmentally when compared to cropping systems using more percent of seed, human labour etc., in their cost of production. An attempt has been made [34] on economic analysis of energy utilization on major cropping systems in Guntur district and summarized the results as detailed below.

Chilli based cropping system require more inputs. Legumes had less cost of cultivation than paddy, chilli and other commercial crops. Human labour followed by chemicals and fertilizers contribute to more than fifty per cent of the cost of cultivation in cereals and commercial crops. Paddy based cropping systems are better in large holdings. Paddy based cropping system are suitable to extensive and low input management. Commercial crops are having better profits for small farmers. Commercial crops are suitable to intensive high input management. Cropping systems which involves pulses in rabi or summer will enhance farmers economy as well as reduce dependence on commercial source of energy.

It was also concluded that [12] concluded that mono cropping based farming systems in North Eastern Region of India is low and it is a high economic risk activity. Over degradation of the soil, excessive depletion of the natural resources like soil, water, vegetation, traditional and conventional agricultural practices will affect the sustainable yields and food security of this region in due course of time. In order to have the sustainable production system in different farming situations zero tillage based resource conservation practices will be an effective alternative to reconcile agriculture with its environment and overcome the imposed constraints of climate change and escalating inputs cost. This study also revealed that in terrace upland, growing mustard on residual moisture followed by upland rice/maize is practised under conservation tillage conditions. Similarly, in valley upland, growing second crop of pea in rice fallow is possible with zero tillage conditions by utilising the residual soil moisture. A long-term study (2006–2009) indicated that zero tillage practice in rice-based system is cost-effective, restored soil organic carbon (70.75%), favoured biological activity (46.7%), conserved water and produced yield (49%) higher than conventional tillage. Hence, conservation tillage practices like zero tillage in different situations viz., terrace upland, valley upland and low-land conditions ensured double-cropping, improved farm income and increased livelihood in rain fed NE India. This was also [13] confirmed the same while reporting about their recent research on resource conservation technologies involving tillage and crop establishment options that are enabling farmers to sustain productivity of intensive rice–wheat systems. Field results show that the resource conserving technologies, an exponent of conservation agriculture, improve yields, reduce water consumption, and reduce negative impacts on the environmental quality [26].

Analysis of cultivation costs in different cropping systems

The analysis of costs in various studies that were reviewed so far was summarized and the conclusions were presented below. The items like fixed costs, operations costs, cost of cultivation in various crops and cropping systems of Andhra Pradesh were taken into consideration while summarizing their trends in the studies that were reviewed so far. This would throw light on the comparative economics, profitability of the cropping system that was present in Andhra Pradesh and helps in crop planning in future.

Operational costs were found higher in chillies among cotton, redgram, paddy and chilles. Total fixed costs were higher in jute, Jowar and castor. That means credit in required for Jute, Javer and castor during the start of the reason and in lump sum, where as it is required in phases and also during the peak season for the chillies followed by cotton, redgram and paddy. Total cost of cultivation consequently the credit requirement would be more for cotton, paddy and redgram and cropping systems based on these crops. Human labour is the highest component in cost of cultivation of paddy based cropping systems. A constant return to scale was observed in all the cropping sequences. This implied that agriculture in Andhra Pradesh continued to be subsistent in nature as one rupee investment gives a return of one rupee only in the cropping systems followed in the Andhra Pradesh agriculture. Major contribution in costs had shifted from bullock labour to manual labour in tribal farming [9]. Machine labour and manures and fertilizers are the other important components of cost of cultivation. From this, it could be concluded that agriculture in Andhra Pradesh in gradually transforming from substance to commercial phase as there was increased use of machine labour and agricultural chemicals in crop production. Use of fossil fuels and chemical in production of crops would have implications on environment and food safety.

Temporal analysis of economics of cropping systems

Economic analysis of various cropping systems at different points of time helps in identifying the trends of various factor that effect the yields economics, gross and net returns, profitability and sustainability of the cropping systems will be of great use in taking decisions both at farmer and policy level.[15]

Rice-Rice cropping systems [28] was initially beneficial but gradually as the time progressed pulses inclusion [43] become inevitable for the profitability of the paddy cropping systems. But during 2014, [17] after analysis of ten years (2000-10) data for rice and wheat was observed current scenario of IGP.

The Contribution of IGP percentage area in India is 48.4% for rice and 74.7% for wheat. The rice wheat system is pre dominant cropping system of IGP. HYV of pulses was recommended and still remained a research gap during the study period to increase the gross returns of the paddy based cropping system. Human labour continued to be critical input in paddy based cropping systems during for study period.

Recommendations were also given [6] based on economic considerations alone, jute–potato–rice, rice–potato–rice and rice–potato–sesame can be recommended as cropping systems for resource-rich growers in the eastern part of the IGP. Systems such as jute–wheat, rice–wheat and jute– rapeseed–rice appear to be most suitable for small and marginal farmers that cannot afford the large production costs associated with crops such as potato.

Critical input in tribal farming was shifted from bullocks labour [10] to human labour [24] System approach and manure use pattern (composition of fertilizers and manures) might have changed in tribal areas during the study period where implications are to be analysed in due course.

Sunflower was identified as an alternative beneficial crop to cotton [34]That means sunflower should be considered as an alternative in case of failure of Bt technology in future course in traditional cotton growing areas in the state.

A case of economic analysis of cropping systems in Guntur district at two different paints of time revealed that shift from food grain dominated cropping system [36] to cotton and chilies based cropping systems [35] Thus, Agriculture in Andhra Pradesh shifted from subsistence to commercial cultivation. Human labour, which was the critical input in agriculture in case of food grain, changed to machine labour and agriculture chemicals during the study period i.e, from sustainable human labour to exhaustive and unsustainable machine labour and agriculture chemicals. The implications thus arise in Andhra Pradesh agriculture needs to be tackled carefully out of the experiences gained from the above reviewed research.

Research on risk preferences and optimal enterprises combinations [27] revealed that changes in risk preference do effect the optimal crops combinations. The typical cropping pattern (Farmers practice) is rational as the farmers meet both food and cash under modest variability of income and insisting on producing more food by the farmers reduce the efficiency and limits the feasible plans. Here the policy comes into action to keep the farmer cultivating cropping systems that are sub optimal at micro level but whose production is essential at macro level. Policy research for recommending optimum crop plans essential at micro level and the required policy to keep the farmers to cultivate sub optimal cropping systems at micro level is to be focused on a continuous basis.

CONCLUSIONS

From the above studies it can be concluded that paddy continues to be the most beneficial crop in Andhra Pradesh. This might be due to agronomic suitability; economic viability as it is also the staple food crop of the state provided it is properly managed in the systems approach. Its rotations with other crops, adoption of HYV suitable to the locations were some of the measures as evident from the above findings. In West Bengal rotation of Potato with rice was formed to be beneficial.

Studies on intercrops in Andhra Pradesh are relevant, since factors like increased cost of cultivation, declaring the crop holiday in some of the traditional crop areas were resulting in making the crops non remunerative.

The findings before the introduction of Bt cotton, which had totally catapulted the cotton crop from a high input economically unsustainable system to a profitable enterprise for the time being. Research on alternative cropping systems that could be economically comparable with cotton can now be regarded as the next best alternative to the cotton based cropping system. But once the sucking pest complex dominate the cotton ecosystem or the Bt technology fails for the American boll warm and tobacco caterpillar then the established findings on the economic analysis of alternative cropping systems for cotton would come into handy.

It could be concluded that vegetables incorporated even at low per cent of total area in a cropping system would contribute to higher per cent of income. By this, they not only contribute to the income security but also the nutritional security of not only of the farm family but also the society as a whole. So it is desirable to include vegetables in every cropping system depending on the feasibility even in small areas. It was [15] also felt that the mono cropping of rice has led to a continuous degradation in soil quality, resulting in a serious threat to the sustenance of the agricultural production system in the high rainfall zone of south Gujarat, India. Their experimental results showed that system productivity for rice–fenugreek (Trigonella foenum-graecum)–okra (Abelmoschus esculentus) was highest (25.73 t ha−1), followed by rice–onion (Allium cepa)–cowpea (Vigna sinensis L.) (24.15 t ha−1); and the lowest system productivity was observed with the rice–wheat (Triticum aestivum)–fallow system (7.85 t ha−1). The sustainable yield index (0.97), production efficiency (102.94 kg ha−1 day−1) and field water use efficiency (15.98 kg ha−1 mm−1) were highest with the rice–fenugreek–okra system. Similarly, net returns (96,286 Rs ha−1), net return per rupee invested (2.83 Rs), monetary production efficiency (385.14 Rs ha−1 day−1) and water use efficiency (59.80 Rs ha−1 mm−1) were maximum with the rice–fenugreek–okra cropping sequence. There were significant effects of various cropping sequences on available nitrogen, phosphorus, potassium and organic carbon content in the soil. Overall, the rice–fenugreek–okra system was found to be the most productive, sustainable, resource-use efficient and remunerative cropping system, followed by the rice–onion–cowpea system in this region.

Further research should be directed towards identifying economically viable cropping systems, which use less fossil fuels and chemicals i.e, environmentally sustainable. Safe, vulnerable and sustainable energy utilization should be the top priority along

with economic feasibility while identifying beneficial cropping systems and was [22] also confirmed the same.

While presenting the results it was concluded that the primary mechanism of the higher yield of the MNR (Organic manure based and LEG (Legume based) cropping systems is due to high moisture-holding capacity of the soils. Soils in the organic plots captured more water and retained more of it in the crop root zone than in the CNV (Conventional chemical based) treatment. Water capture in the organic plots was approximately 100% higher than in CNV plots during September's torrential rains. Research findings on the effect of price variations on cropping patterns of main crops indicated that the crops with low price variations (i.e. Rice) were excluded from cropping pattern, where the expected income was declining. In that place some products that have high price variations but high yields remain in cropping patterns. It was suggested that in order to raise the acreage and production of food crops, in addition to price policies attention must be paid to non-price policies, which can increase the yield. Since the emerging cropping patterns involved crops that have high price variations risk analysis and economic analysis with decision making under risk in agriculture in gaining importance.

The overall analysis of the above conclusions revealed that the cereal based farming system was predominant in terms of area occupied in the sub-continent. It was also confirmed and reported [38] that increased productivity brought economic benefits to farmers and led to the establishment of Wheat-Rice Cropping Pattern (WRCP) as the main agricultural system of Punjab which more recently has become reliant on underground water resources, agricultural machinery, chemical fertilisers and pesticides. Degree of diversification was inversely proportional with the size of the farm in Sothern agro climatic zones. Paddy + Paddy system was found most important in terms of contribution to farm income in the area. Its share is more than 59 per cent. However its importance decreases with increase in size of holding due to decreased contribution of livestock. Paddy+Paddy+Livestock system ranked second with more than 32 per cent share. The maximum sub farming systems were either paddy or oil seed involved the farming system in scarce rainfall zones of India. Cotton based along with horticulture gardens and cash crops are the predominant farming system in the Deccan plateau of the sub-continent. Pulses, oil seeds followed by sugar cane and horticulture based farming systems were next to cereal based and cotton based farming system. The numbers of farm house holds are mostly dominated by following paddy or sugarcane based system in the river basins. Other farming systems are in negligible proportion in basin agro climates. This showed the high amount of specialization in agriculture in the river basins and command areas. Sources other than farming were also contributing towards the household income in hilly and tribal areas. This showed the lack of strong agricultural base to provide sustained livelihood in hilly and tribal areas.

Finally, research revealed that India having relatively diversified cropping patterns. The experience gained from cropping system analysis in one situation could be carefully modified and adopted in another situation along with risk analysis and policy analysis from cropping system point of view. The thorough review of this type would benefit the farming community and results in sustained agricultural production in the study area.

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