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Review Article *Natural Resource Management*

Viable Options for Diversification of Rice in Non-conventional Rice–conventional Wheat Cropping System in Indo-Gangetic Plains

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Abstract

The Indo-Gangetic plain (IGPs) is a relatively homogenous ecological region in terms of vegetation. This plains follows mainly'Non-traditional rice-traditional wheat' cropping system in Trans and upper IGPs and 'Traditional rice-non-traditional wheat' cropping system in middle and lower IGPs. The rice and wheat serve and still serving as a backbone of Indian food security with 76 % share in total food-grain production. The growing concern of adverse impact of rice cultivation in 'Non-traditional rice-traditional wheat' were reflected in to depletion of water resources, degradation of soil fertility and environmental problems such as pollution due residue burning and ground water pollution. This creates a scope for diversification of this system to bring sustainability of resource use in Indo-Gangetic plain. The potential options available for diversification of rice in this system include replacement of rice with maize or suitable legumes or oilseeds or cash crops (sugarcane or cotton) or horticultural crops. Along with these options, introduction of medicinal and aromatic plants and break crops also stand as potential options. Diversification through changing cultivation methods and resource management strategies in rice production system is also possible. The present review discusses the reasons for diversification of rice in 'non-traditional rice-traditional wheat' cropping system along with needs and issues of rice diversification in IGPs. In this review, attempt has been made to suggest different viable options available for diversification of rice in this cropping system with the help of research done on this issue in IGPs.

Keywords: Diversification, Indo-gangetic plains, policy initiatives, rice, wheat

1. Characteristics of Indo-Gangetic plains (IGPs)

The IGPs is a relatively homogenous ecological region in terms of vegetation with nearly 13 % of the total geographical area of India and it produces about 50 % of the total food grain to feed 49 % of population of India (Pal et al., 2009). In the western part of IGPs wheat is the dominating crop; while rice dominates eastern region. The IGPs are spread from 67^0 to 96^0 E longitudes and from 20^0 to 33^0N latitude. Indian portion of IGPs extends from $21^0$31' to $32^0$20' N and $73^0$16' to $89^0$52'E and is spread over the states of Punjab, Haryana, Delhi, Uttar Pradesh, Uttaranchal, Bihar and West Bengal as well as small part of Jammu and Kashmir, Himachal Pradesh and Rajasthan (Ali et al., 2000). It extends from Assam and Bay of Bengal on the east to the Afghan border and Arabian Sea in west and

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cover India, Bangladesh and Pakistan (Prasad, 2005).

The IGPs in India comprises, i) The trans IGP (trans IGPs classified in to two groups, trans IGP in Pakistan and trans IGPs in India). It comprises Punjab, Haryana, union territories of Delhi and Chandigarh. ii) Upper IGPs (It comprises of Western and part of central Uttar Pradesh), iii) Middle IGPs (comprises of part of central, eastern U.P and Bihar) and iv) Lower IGPs (comprises West Bengal and part of Bangladesh (Chauhan et al., 2012). Annual rainfall shows the increasing trend as we moves from west to east in IGPs. Western part of IGPs has annual rainfall of 500-800 mm, where as in the eastern part rainfall increase up to 1000-2000 mm. The climate in the western part of Indo-Gangetic plain is semi-arid type where as in eastern part it is sub-humid. As we move from west to east, the soil texture becomes heaver and drainage is impeded. Agricultural productivity and farm returns also show a declining trend from western to eastern IGPs (Singh, 2010).

2. Rice Wheat Cropping System (RWCS)

Rice-wheat cropping system (RWCS) is followed on an estimated area of 28.5 million ha, (Prasad, 2005) including 13 million ha in China (Jiaguo, 2000), 12.3 million ha in India (Kumar et al., 1998), 2.2 million ha in Pakistan, 0.5 million ha in Nepal and 0.8 million ha in Bangladesh (Ladha et al., 2000). These five RWSC countries are not just any five of the more than 200 countries of the world. They represent 43 % of the world population on 20 % of the world arable land (Sinhg and Paroda, 1994). According to Singh and Kaur (2012) the area of RWCS in India, Pakistan, Bangladesh and Nepal is 10.0, 2.2, 0.8, and 0.5 million ha, respectively. This system represents 32% of the total rice area and 42% of the wheat area in these countries. There are two types of RWCS emerged in this plains during green revolution period (Chauhan et al., 2012). First one is 'Non-traditional rice-traditional wheat' cropping system in trans and upper Indo-Gangetic plains (IGPs) which is mainly wheat growing area before green revolution; while second in rice growing area of middle and lower IGP before green revolution is the 'traditional rice-non-traditional wheat'. To achieve self sufficiency in food-grain production, practice of monotonous monoculture of rice and wheat in IGPs get started. The contribution of RWCS to area, production, fertilizer consumption and providing food and nutritional requirement of Indian population can effectively depict the picture of importance of RWCS in achieving self sufficiency in food-grain production (Table 1). This highly intensive and specialised RWCS in a short period of time replaces other coarse cereals, millets and others crops. Practice of monoculture of rice and wheat sets monopoly of few crops (rice and wheat in case of IGPs), to fulfil our food basket and makes our food basket more monotonous. Monoculture of RWCS also exert excessive pressure on resource due to wish of getting more from applied resource without thinking of natural resources such as soil, water, energy, etc. Collective effect of all these leads to raising variety short and long term problems in RWCS as enlisted in Timsina and connor (2001).

Table 1: Share of rice and wheat in area, production, nutrition and resources consumption

Sl. No.	Particular	Share (%)
1.	Share in total food-grain production	75.6
2.	Share in total cereal production	82.5
3.	Share in total area under food-grain crops	57.6
4.	Share in total area under cereal crops	74.8
5.	Share in irrigated area of food-grain crops	80.6
6.	Share in irrigated area of cereal crops	92.4
7.	Share in supplying food requirement of Indian population	80
8.	Share in supplying nutritional requirement of Indian population	60
9.	Share in total nitrogen (N) consumption of food-grains	83.0
10.	Share in Phosphorus (P) consumption of food-grains	78.1
11.	Share in potassium (K) consumption of food-grains	88.4
12.	Share in total nitrogen (N) consumption of all crops	52.5
13.	Share in Phosphorus (P) consumption of all crops	48.5
14.	Share in potassium (K) consumption of all crops	45.4

Timsina and connor (2001); Anonymous, 2017a; Anonymous, 2018; Anonymous, 2018a; FAI, 2014; Gill et al., 2008a

3. Future of Rice-wheat Cropping System

Present situation of RWCS is mainly depicted in terms of declining natural resource based due to excessive bourdon and decrease in productivity and profitability in absence of governmental support in terms of subsidy and incentives. Over the period, the thumb rule of producing more in less resources' is mostly followed without giving due consideration for conservation of natural resources for future. This emphasises threatened the RWCS in IGPs and forces to make changes in present RWCS for future. The need for shifting some area for rice and wheat in Punjab, Haryana and western U. P. was also reported by Singh (2012).

There are three main ways for making change in RWCS. First is to make the RWCS sustainable by removing defaults and changing it towards more resource efficient and sustainable (Table 2). A concern of sustainability of RWCS was reported widely in literature (Singh et al., 2012; Chauhan et al., 2012;

Table 2: Possible interventions in presently followed rice in RWCS of IGPs

Present rice	Future Rice
high yielding varieties	Hybrid rice and genetically modified rice (Spielman et al., 2013)
Water guzzling crop	Water saving practices (system of rice intensification and aerobic rice) (Zhao et al., 2009; Prasad, 2011)
Imbalanced and non-appropriate fertilizer application practices	Precision nutrient management, Site specific nutrient management, inclusion microbial inoculants in nutrient management (Singh et al., 2016)
More energy consuming for puddling, excessive fertilizer use.	Energy saving through aerobic rice, decrease fertilizers use through use of cost effective microbial inoculants and green manuring crops
No price tag on natural resources	Price tag on natural resources
Inappropriate management of crop residue	Effective utilization of crop residue for improvement in soil health (Singh et al., 2008)

Ladha et al., 2000; Prasad and Nagarajan, 2004; Prasad, 2005). This can be achieved through removing or modifying some management practices which have adverse impact on natural resource base and responsible for stagnating productivity. Along with management practices, change of present rice ideotype with high yielding irrigated rice plant for future (Prabhakara Setty, 2016) was also essential. Second way is intensification of present RWCS with incorporation in summer legumes (green gram), growing of green manuring crop and growing of catch crops which have restoration effect and third way is diversification of RWCS.

4. Diversification of Rice-Wheat Cropping System

Diversification of RWCS can be achieved through various options like:

- Replacing rice,
- Replacing wheat,
- Replacing whole cropping system,
- Addition of third crop to make RWCS sustainable,
- Introduction of break crop in the cycle of rice and wheat,
- Through introduction short duration vegetable crop or medicinal and aromatic plants
- Through farming system approach and
- Shifting rice cultivation from trans and upper IGPs to middle and lower IGPs, as the lower and middle IGPs was the traditional rice growing area.
- Change in rice cultivation method to more resource conservative and efficient methods.

Diversification also done through changes in varieties and farming practices, such as cultivation of *Basmati*(scented) rice instead of high yielding varieties, which gives high income due to better market prices (varietal diversification). In farming practices, following organic farming gives more income even though yield may reduced, due to higher prices for organically produced food.

5. Need for Diversification in IGPs

Before going in detail about diversification it is necessity to discuss need of diversification in IGPs. Necessity of crop diversification in India were mentioned by several authors (Shiferaw, 2012; Let, 2011; Walia et al., 2011; Ranchandran Nair, 2016; Lama et al., 2018) and when land to man ratio is low, the need for alternative crop and cropping system was also reported by Dawari et al. (2012). Diversification is one among the five selected pathway reported by Dixon et al. (2001) by which farm household escape poverty. Importance of agricultural diversification for prosperity of small holders was also mentioned by Birthal (2012 and 2016); while importance of diversification in increasing farmers' income was also reported in NITI policy paper (Anonymous, 2017 and by Khanam et al. (2018). Diversification was also a one of the several ways to mimic natural ecosystem which helps in brining sustainability in agro-ecosystem (Dore et al., 2011). The need for shifting some area for rice and wheat in Punjab, Haryana and western U. P. was also reported by Singh (2012). He also emphasises the diversification of rice and wheat in trans-IGPs.

The long-term projections reveal that by 2030, 36 to 40% of the dietary energy demand has to be met from commodities other than food-grains (Paroda and Kumar, 2000). This demands the need of diversification in IGPs. Kalaiselvi (2012) found that, there is continuous surge for diversified agriculture in terms of crops, primarily on economic considerations. He reported that, Jammu and Kashmir have lowest number of crop (13) grown; while Karnataka (27) is stands first in terms of number of crops grown.

6. Issues of Diversification in IGPs

Along with needs there are some issues of crop diversification in IPGs which necessary to take in to consideration. Some of the important issues regarding diversification in IPGs are mentioned as reported by Garg et al. (2006):

- In the diversification exercise, farmers are not ready to compromise with their current returns. Any alternative system has to be equally paying on its own or has to be made through system of incentives and disincentives.
- Resource conservation is at the threshold of psyche of farmer but does not figure well in their crop management strategies. Resource conservation options in absence of good economics may not appeal to the end users.
- Stability of production, prise and ultimate returns in alternate crops viz., pulses and oil seeds is inherently low. It may not be worthwhile to target one crop. It is imperative to

work out the permutation and combination of crops where cropping system could possibly be stabilized.

- The extent and objective of diversification should be plain clear. The hot pursuit may land in food crises and glut condition for alternate crop particularly so in case of horticultural crops. Diversification never means the mere substitution of one crop by another crop. It must leads to resource conservation with favourable economics in long run.
- Support price for alternate crops in consonance with state procurement or any other suitable mechanism of market intervention is must and also support price should be such to ensure an edge in returns for a reasonably long period. It is for the planner to examine all the pros and cons before embarking on it.
- The subsidy component in RWCS is quite substantial and there need to be a mechanism to cross this subsidy as bonus for alternate crops.

7. Selection of Rice for Diversification in IGPs

As above discussed, there are variety of options for diversification of RWCS in IGPs. Diversification of wheat was discussed in detail by Singh et al. (2011); Singh et al. (2010); Kachroo et al. (2014) and Saumi et al. (2004). Diversification of rice was a main concern for Trans, upper and part of middle IGPs which includes Indian states of Punjab, Haryana and Western Uttar Pradesh. This region follows non-conventional rice-conventional wheat cropping system (RWCS) and wheat is well suited to this region. Hence, this review emphasizes diversification of rice. There are some facts which justify the selection of rice to diversify RWCS:

- Rice is a high water demanding crop. To meet its water requirement lot of groundwater is pumped out, which results in to decline in water table in trans and upper IGPs. According to Kumar et al. (2010) the area having a water table below 9 m was increased from 3% in 1973 to about 90% in 2004 and almost 100 % in 2010.
- Long term cultivation of puddle rice results in formation of a hard pan with consequent increase in bulk density and decrease in hydraulic conductivity below the plough layer (Singh et al., 2009). The hard pan impedes root penetration of subsequent upland crop which is wheat in RWCS.
- The RWCS has not only resulted in mining of major nutrients (N, P, K, and S) from soil but also has created a nutrient imbalance, leading to deterioration of soil quality.
- Cultivation of rice makes condition conducive for multiplication of insect-pest and diseases.
- Increased population of mosquitoes due to stagnating water which help in their breeding.
- Glut in market due to over production of rice, thereby causing market problems and social tensions.
- Area under rain-fed upland rice comprises 7.0 M ha in India which is subjected to water stress at different growth phases due to low and erratic rainfall. In order to avoid the risk and provide better returns to the farmers, it is needed to diversify the rainfed uplands rice with non-rice crops, which are drought tolerant, less moisture-requiring and deep-rooted such as pulses and oilseeds (Behera and Jha, 1999). There is fear that Punjab, the most forward state in agriculture in the country, may face severe water scarcity due to continuous pumping out large volume of water.
- In case of wheat, it is a traditional crop of trans and upper IGPs and also climatic condition required for its growth is present in this area. Rice is non-traditional crop, grown in that area due to availability of resources and governmental incentives. Now, resource base is declining and government is also in favour of diversification of original green revolution area. This situation justifies selection of rice for diversification of RWCS in IGPs.

8. Viable Options for Diversification of Rice in IGPs

8.1. Substitution of rice with maize in IGPs

Among cereals available for substitution of rice, maize stands first. Maize is called as 'king of fodder' and 'queen of cereal' due to its high genetic yield potential. Now a day's breeders are also calling maize as a 'promising cereal' as maize is only cereal after rice and wheat which has capacity to take baton of world food security due to high yield potential. Maize is also called as 'future cereal' as rice and wheat yield showing stagnation. So to meet the food demand of increasing population, we need to find third crop in future and there maize stands. Importance of maize as a potential source of human nutrition and health was mentioned in Shah et al. (2016); while Murdia et al. (2016) discussed the different uses of maize. Maize can be used for human consumption as grain (flour, flakes and popcorn) or vegetable (sweet corn and baby corn) and livestock feeding as grain, leaves, stalks and silage, which is not in case of rice as its straw is not preferred by cattle. Along with that, maize has industrial uses like production of starch, oil, sweeteners (corn syrup) and thickening agents. Maize is mostly used cereal for bio fuels i.e. ethanol production. It is this use of maize which is mostly responsible for increasing prices and demand of maize in international market. Singh et al. (2012), Dass et al. (2012) also mentioned the potential of maize for diversification.

Maize is grown at wider spacing as compared to other cereal crops. This space is efficiently used by growing of additional intercrop which further provides option for diversification of cropping system and farm income. Potential of maize for diversification was also mentioned by Dass et al. (2012). At the same time, growing of intercrop used additional resources which otherwise stolen by weed during early growth period. Diversification of diet with a positive bias towards eggs, meat and meat products increase its demand. To fulfil this market demand business of raring of birds like poultry and animal like goat and pig is increasing. To feeding concentrates to poultry birds, goat and pig, maize is the best options. Infect most of the maize produces in used as a cattle feed. This also increases scope for growing of maize.

There are some **c**onstraints for substitution of maize for rice. Due to sufficient availability of rice and wheat, maize is not used for consumption till date; hence incentives on maize cultivation are less as compared to rice. This can be realized from minimum support prices which is low in case of maize (₹ 1700/ quintal) as compared to rice (₹ 1,750 and ₹ 1,770/ quintal for common paddy and grade A paddy).This reduces monitory returns from maize. At the same time maize do not procured for distribution in public distribution system. Maize plant is sensitive to both excess and deficit of water. Among other cereals, sorghum and pearl millet are other crops that can be replaces rice. Both crops are highly efficient in using water however have low productivity and are suitable for rainfed condition. Cultivation of sweet sorghum can be better alternative as it gives more income from ethanol, fodder and grain production (Miri et al., 2012).

8.2. Substitution of rice with legumes and oilseed crops

The ameliorative effect of including legumes in continuous cereal cropping systems such as RWCS has long been known and emphasized by several others (Singh et al., 2011; Lauren et al., 2001; Johansen et al., 2000; Ali et al., 2012; Stagnari et al., 2017; Davari et al., 2012). Over time, legume crops have generally declined in importance due to low yield potential of legumes, as compared to rice and wheat and their susceptibility to many abiotic and biotic stresses. The use of leguminous crops was also recommended by Singh et al. (2012) in their extensive review to detect research needs and direction for sustainability of rice based cropping system. According to them, legumes plays important role in improving and sustaining the crop productivity with the judicious use of natural resources, reduce the use external inputs and production costs in rice based cropping system. Nutritional benefit of legumes in terms of their protein, vitamin and mineral nutrient content over rice and wheat were summarised in Lauren et al. (2001). Pulses found a very good position in rice-fallow system which was occurred on nearly 11.7 million ha area (Gosh et al., 2012) in India.

Pulse production was 6.5% out of total food-grain production and occupies 19.7% area out of total area under food-grain (Anonymous, 2016; Tiwari and Shivhare, 2016). Legumes in the IGPs share 13.6% of the total area in the country and account for 15.8% of the total production. The issue for concern is that both area and production of legumes are declining (Ali et al., 2000). The important legume and oilseed crops which can be grow to replace rice in the IGPs are Pigeon-pea (*Cajanus cajan* (L.) Millsp.), Groundnut (*Arachis hypogaea* L.) and soybean (*Glycine max* (L.) Merr.); while the major legume and oilseed based cropping systems in western IGPs are pigeon pea-wheat, groundnut-wheat and soybean-wheat. Legumes and oilseeds crops like Black gram *(Vigna mungo* (L.) Hepper), Mung bean (*Vigna radiata* (L.) Wilczek) and Sunflower (*Helianthus annuus* L.) are mainly grown during spring/summer season and to a small extent during rainy (*Kharif*) season. Importance of inclusion of legume in RWCS in IGPs was mentioned in Singh et al. (2011) and Chaudhary et al. (2009).

8.3. Potential of horticultural crops to replace rice in IGPs

The major driving forces for diversification according to Jat et al. (2006) on the supply side is serious natural resource management problems, including the unsustainable exploitation of water and soils, inefficient use of chemical inputs and emerging or worsening disease and pest problems. On the demand side they are being transformed by market forces, changing consumer demands, prosperity and nutritional security (Jat et al., 2006; Kashyap et al., 2016; Saini et al., 2018; Negi et al., 2018). Both the thrusts imply an increasing role for horticulture crops in diversification of rice in RWCS. The market potential of horticultural crops needs to be explored in context of diversification of RWCS in IGPs. In case of fruit crops, there is possibility of intercropping during early year of establishment. This will generates income which can meet out expenditure during initial years of crop establishment. In case of vegetables cultivation, mainly in peri-arbun area around the metropolitan cities, it is high income generation farming. This is mainly due to market proximity, which tackles the problem of perishable nature of vegetable crop and allows fresh vegetable to rich in market at appropriate stage of crop growth for which demand is more in market. Another reason is more market demand of vegetables in cities not only due to higher population but also due to increased awareness among peoples for nutritional value of vegetable.

The potential of horticultural crops for diversification is constrained by their long duration which not only replaces rice but replaced whole cropping system and it makes sometimes practically difficult to replace the rice through fruit crops and there vegetables stands. The perishable nature of fruits and vegetable is more important and this is the reason of having more commission charged by middleman. This decreases the farmer share in consumer money and most part is remains with middleman. At the same time we can't wait for longer time to get more market price as like in case of grains crops. Prise fluctuation is another aspect which needs to be taken in to consideration. This fluctuation is mainly due to glut condition in market as happen in case of potato, and Cole crops likes cabbage and cauliflower during their peak arrival. A success of vegetable cultivation depends on marketing of vegetable. Vicinity of market is more important and due to this reason farmer in peri-urban area gets more net income compared to farmers away from cities. Increase in fuel prices increase transport cost which further adds to production cost and decrease net returns. Vegetable based cropping system provides opportunity to increase cropping intensity as these crops are mainly harvested earlier than grain crops. They also increase net returns and benefit: cost ratio (B: C) which is much higher than RWCS and this was justified in Prakesh et

al. (2007), Walia et al. (2011), Singh et al. (2016) and Kumar et al. (2012).

8.4. Substitution of rice with cash crops in IGPs

Among cash crops, sugarcane and cotton are the available options for diversification of rice in RWCS in IGPs. As both crops are cash crops, they giving higher returns provided conditions are suitable for their cultivation. Sugarcane (*Saccharum sp*.) crop occupies important position in Indian agriculture, as it is the second largest organised agro-industry in the country, next only to textiles. It is a cash crop unique in the sense that a number of succeeding ratoons are taken from a single planting. The main product of sugarcane is sugar in Indian context, while most of the sugarcane grown in Brazil for ethanol production. Along with sugar, various products such as Khandsari, Jaggery (gur), syrups, etc. are prepared from sugarcane juice. Two important by-product of sugar industries are bagasse and molasses. Bagasse is used as a fuel, for production of fibre board, papers and plastics. Molasses is used in distilleries for the manufacture of ethyl alcohol, butyl alcohol, citric acid, etc. It is also used as additives to feed for livestock. Green tops of cane are good source of fodder for cattle. Net returns of ₹ 390.4×10^3/ha and ₹ 302.3×10^3/ha with B: C ratio of 5.8 and 4.2 during first and second year were reported in sugarcane cultivation at Varanasi, Uttar Pradesh during 2008-09 and 2009-10, respectively (Dev et al., 2011). These net returns were higher than net returns of RWCS as reported by Walia et al. (2011) and Singh et al. (2008). With this multifarious use of sugarcane it can be stand as a good alternative for rice in IPGs.

Cotton as a crop as well as a commodity plays an important role in the agrarian and industrial activities of India. Cotton popularly known as "White Gold" is grown mainly for fibre. In addition to this, cotton seed is the important source of oil which has industrial uses. India has been a traditional home of cotton and cotton textiles. In India all the four cultivated species of cotton are grown. The economy of the regions where it is cultivated is consistently influenced by its production and processing sectors, and by generating direct and indirect employment to people. Intercropping is possible in both sugarcane and cotton, which generate additional income and efficiently uses the applied inputs not used by crop and taken by weed during early crop growth period due to slow growth. Further Cotton-wheat cropping system (CWCS) is a long established crop production system of north-western plains of IGPs. While RWCS is a grain production system, CWCS is a grain plus cash cropping system which improves the economy of farmers through cultivation of cotton as an industrial commodity and wheat as a component of food security (Mayee et al., 2008).

There are some constraints which need to be considered while adopting these crops instead of rice. Both crops are long duration compared to rice. Growth of cotton is indeterminate, this creates problems in harvesting. Cotton requires 3-4 picking which is again labour intensive operation. Weed problem is more severe during early growth of both the crop due to wider spacing and slow growth during initial period. With the introduction of Bt. Cotton in India, a problem of boll warm is not much severe as compared to before introduction of Bt. Cotton. However, most of the Bt. cotton hybrids being cultivated are susceptible to sucking pest (Kranthi et al., 2011; Blaise et al., 2014). Dhillon and Sharma (2013) reported significantly more white fly population on Bt. cotton than non-Bt cotton.

8.5. Medicinal and aromatic plants and plantation crops in IGPs

Cultivation of medicinal and aromatic plants (MAPs) on small area is remunerative. The positive side of these crops is that, these crops mature in short period of time or sometimes give cutting at frequent interval as in case of Lemongrass. This leads to increase in liquidity of capital invested by farmers. Secondly, there is less chances of glut condition in market as the area under MAP cultivation is less, MAP have large array of crops having different use which avoid situation as happen due to growing of single crop and market demand is high due to more awareness about natural therapy (*Ayurvedic* medicine) and increased uses of natural perfumes due to less side effect. Importance of aromatic crops in crop diversification was reported by Prakash Rao (2012) and Prakash Rao (2009) in general for Indian situation; while Malik (2007) and Khan et al. (2010) mentioned importance of MAPs for diversification in Karnataka, Uttarakhand and Madhya Pradesh, respectively.

Besides that, the factors that affect the cultivation of MAPs are non-availability of high yielding varieties and quality seed of MAPs. This is mainly due to most of MAPs are newly comes under cultivation and previously these are collected from forest area. At the same time standard cultivation practices are not developed yet in many MAP. Awareness among the farmer is less about the potential of these crops. Another important point is that, a success of MAPs cultivation depends upon the post harvest management, as the price gained for row material less as compared to processed material. So, effective management of post harvest processes such as oil extraction is essential to realise their full potential. Intercropping of MAPs in poplar plantation is working well and giving addition returns during initial years of poplar establishment (Gill et al., 2008).

8.6. Forage and break crops

Forage crops are not able to compete with rice for land. They can support addition enterprise of dairy and becomes important part of farming system which involves dairy enterprise. Forage crop such as berseem can also act as a break crop in RWCS which help in reducing weed population of succeeding wheat crop (Tripathi et al., 2004). Introduction of break crop such as maize, pigeon pea, soybean and fodder sorghum instead of rice and berseem and mustard instead of wheat once in three year cycle of rice-wheat is also followed

to get rid of problems arises due to continuous RWCS in IGPs. Along with diversification of either rice or wheat, intensification of system with introduction of legume and vegetable crops such as vegetable pea or green gram during lean period is also practiced on some part of IGPs.

8.7. Change in rice cultivation method to more resource conservative and efficient methods

Adverse effect of rice cultivation in non-traditional area can be handled constrictively through changing cultivation methods from conventionally followed puddle transplanted rice(PTR) with flooded condition to other methods such as aerobic rice system (ARS) (Prasad, 2011) and system of rice intensification (SRI) (Uphoff, 1999; Dobermann, 2004). These changes in methods reduce the burden on natural resources such as water and increase productivity of rice per unit of resources used even though productivity of rice per unit area was same in PTR, SRI and ARS. Water saving in SRI was mentioned in Singh (2013) and Shahane et al. (2015); while higher net returns in SRI over PTR was mentioned in Jat et al. (2015) and shahane et al. (2017). Benefits of water saving by adoption ARS over PTR was mentioned in Prasad (2011) and Farooq et al. (2009).

9. Comparing Different Cropping System for their Productivity, Economics and Resource Use in IPGs

In order to search viable option for rice in RWCS, different crops and cropping system were studied in different location over IGPs for variety of parameters. First and foremost parameter to make it convenient to say viable substitute is rice equivalent yield (REY). All nine different cropping systems studied by Walia et al. (2011) shows higher REY (except cotton-gobhi sarson, cotton- african serson and cotton- wheat). Diversification of inbred rice with hybrid rice, *Basmati* rice and addition of berseem (first cutting for fodder in winter and kept for seed setting in summer) increase REY (Kumar et al., 2012). In another study at Modipuram (Uttar Pradesh), REY was found lower in maize-wheat cropping system which might be due to change in location; while Hargilas (2016) recorded 7.77 to 11.87 t ha^{-1} maize equivalent yield of maize-wheat cropping system. Similarly, Shambhavi et al. (2018) recorded 7.67 t/ha maize equivalent yield of maize-wheat cropping system. Lower yield pigeon pea reduces REY of pigeon pea-wheat cropping system (Meena et al., 2012). Replacement of rice with sugarcane gave higher yield but it at takes 9-12 month to get ready for harvest.

The REY is a parameter of biological significance. It need to convert REY in to economic terms which have strong influence on the adoption of new crop and cropping system. Substitution of rice with maize and groundnut gave more net returns than RWCS. Cotton also found better substitute and gave higher net returns and B: C ratio than RWCS when it was followed by cultivation of Gobhi sarson than African sarson. Addition of legume during summer season (green gram and black gram) and fodder crops (Pearl millet and Berseem) increase returns due to their low cost of cultivation and short duration. Substitution of rice with pigeon pea also gave higher net returns as reported by Singh et al. (2005). Replacement of inbred rice varieties with hybrid and Basmati increases net returns and B: C ratio (Kumar et al., 2012). Production efficiency is the function of duration of crop or cropping system for which they occupy the land and expressed in terms of kg ha^{-1} day^{-1}. Maize-wheat, maize-wheat-mungbean, maize-potato-mungbean, maize-potato-onion, groundnut-potato-pearl millet (F) and groundnut-toria+ gobhi sarson cropping system recorded higher production efficiency compared to RWCS (Walia et al., 2011).

Higher water requirement of rice is one reason for arising issue of diversification of rice in Trans, upper and part of middle IGPs where rice is mostly grown under irrigated condition. So, selected option for substitution of rice is considered viable if it requires less water than rice. This water saving is judged by measuring amount of water applied through irrigation (cm), water productivity (kg grain m^{-3} irrigation water), system water requirement (mm) and system water use efficiency (kg ha mm^{-1}). Substitution of rice with cotton (71 cm) and maize (73.7 cm) requires lowest water among nine different cropping system studied by Walia et al. (2011) which leads to higher water productivity (1.770 and 1.583 kg grain m^{-3} for maize and cotton, respectively) compared to rice (0.573 kg grain m^{-3}). Cropping system such as groundnut-potato-pearl millet (F), groundnut-toria+ gobhi sarson recorded higher water productivity (2.298 and 2.417 kg grain m^{-3}, respectively) mainly due to lower water requirement of groundnut, pearl millet and sarson. In case of maize-potato-mungbean and maize-potato-onion cropping system, higher water productivity (2.178 and 2.151 kg grain m^{-3}, respectively) was mainly due to higher yield of potato and onion and lower water requirement of maize and mungbean.

Along with water, other resources such as land and energy also taken in to consideration while selecting crops for substitution of rice in RWCS. With studying short term benefits of crops and cropping system their sustainability index also need to be studied which is calculated from Sustainability index (S.I.). Crops like maize, cotton and groundnut recorded lower sustainability index than rice but difference in S. I. is marginal. Addition of third crop during summer and replacing inbreed rice with hybrid rice in inbred rice-wheat- green manure system increase sustainability. In respect of energy production, replacement of rice with maize in RWCS increases energy production (40.26×10^6 k. cal Vs. 39.91×10^6 k. cal). Hybrid rice also increase energy production if sown instead of inbreed rice by 5.8×10^6 k. cal in RWCS. Land use efficiency (LUE) was found higher with Basmati rice-lentil- green fodder (GF) (maize+cowpea) (90.4%) which was followed by hybrid rice-potato-green gram (87.6%) and hybrid rice-mustard-black gram (86.3%) (Kumar et al., 2012). Highest land use efficiency were found in case of maize+ tomato+garden pea+ french

bean and maize+french bean+garden pea+french bean which was 96% in both cropping system (Prakesh et al., 2007).

10. Policy Initiatives for Diversification of Rice in IGPs

To succeed in any issues and to get the think done, support of policies is needed. Importance of policy and market reforms in achieving sustainable crop diversification was emphasized by Rao et al. (2012).The issue of crop diversification is talked not only in scientific society but also by the policy makers and in terns by government. Finance ministry of India in budget of 2013-14 and 2014-15, provided an amount of ₹ 500 and ₹ 250 crores for crop diversification in original green revolution states to divert the area of water guzzling crop such as rice to alternate crops from *kharif* (rainy) season with 100% government of India assistance (Anonymous, 2013 and Anonymous, 2016b). Along with diversification of rice, another sub-scheme of RKVY initiated in 2010-11 called 'Brining green revolution to Eastern India (BGREI)' to increase rice production in this conventional area of rice cultivation. They mention crop diversification as the shift from the regional dominance of one crop to regional production of a number of crops, to meet over increasing demand of cereals, pulses, vegetables, fruits, oilseeds, fibers, fodder, grasses, etc. The aim is to improve soil health and to maintain dynamic equilibrium of the agro-ecosystem.

The committee of secretaries examine nine major states comprises of three RWCS states viz., Punjab, Haryana and Uttar Pradesh, Two rice dominating states viz., West Bengal and Bihar and four other states viz., Andhra Pradesh, Maharashtra, Karnataka and Rajasthan. The committee concluded that the original green revolution states were facing problem of stagnancy in yield and over-exploitation of groundwater resources which call for immediate diversification in crops through promotion of the technological innovations in order to enable farmers to choose appropriate crop alternatives. The programme is to be implemented in three states viz., Punjab, Haryana and western Uttar Pradesh. The notified over-exploited and critical blocks based on recommendation of central ground water board of major paddy growing districts of each state would be identified for implementation of crop diversification programme. At least 5% of the area under paddy in identified blocks would be diverted toward alternate crop during 2013-14.

11. Conclusion

The increasing level of degradation of natural resources due to rice cultivation in non-traditional area (Trans and part of upper IGPs) need to be addressed in economically viable and ecologically sustainable way. Cultivation of other cereals (maize), pulses and oilseed (soybean and pigeon pea), cash crop (cotton and sugarcane) as well as vegetable and medicinal and aromatic plants stand as a possible option for rice diversification with government policy support and incentives.

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