Approaches for enhancing resource efficiency under changing climate with special reference to crop diversification in Sikkim Himalayas

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Abstract:

A diverse agro-climatic region makes Indian agriculture more vulnerable, basically due to over dominance of population on agriculture and poor coping mechanism. Crop diversification can improve resilience in a variety of ways: by engendering a greater ability to suppress pest outbreaks and dampen pathogen transmission, which may worsen under future climate scenarios, as well as by buffering crop production from the effects of greater climate variability and extreme events. In the agricultural context, diversification can be regarded as the re-allocation of some of the farm's productive resources, such as land, capital, farm equipment and paid labour, into new activities for value-addition and provision of services to other farmers. Sikkim Himalaya represents a hotspot of agro-biodiversity. Here, agricultural diversification is picking up momentum in favour of high-value food commodities primarily to augment income rather than the traditional concept of risk management. The livestock sector is the principal income-generating source in agriculture followed by the crop sector. Several non-food-grain crops such as fruits, vegetables, and medicines have substituted mainly coarse cereals in the farmers' pursuit for higher income. Whereas fruit cultivation has been adopted in a big way in the temperate belt, the same does not appear to enjoy any comparative advantage in non-temperate belt.

Keywords: agro-climatic region, Crop diversification, agro-biodiversity and non-food-grain crops

INTRODUCTION

Global climate change makes some impact on different types of crops and therefore affects production and productivity and ultimately the world's food supply. Substantial study has undergone to work out that how farming is affected in different parts of the regions, and by how much; and whether the net result may be harmful or beneficial to which type of crop. However, major uncertainties limit the correctness of current models and or projections. Some of them are relating to the degree of temperature increase and its geographic distribution and other may pertains to links changes likely to occur in the precipitation patterns that determine the water supply to crops, and to the evaporative demand imposed on crops by the warmer climate. Some areas could experience longer, more intense droughts, resulting from higher summer temperatures and reduced precipitation makes difficult to crop production. In Indian condition climate change and its variability from place to place are placing challenges and ultimately

impacting Indian agriculture. A diverse agro-climatic region makes Indian agriculture more vulnerable, basically due to over dominance of population on agriculture and poor coping mechanism. Some researchers have already reported the negative impacts on yield of rice, wheat and other crops in parts of India due to augmented temperature, increased water stress and reduction in number as well as timing of rainy days which in turn would result in greater instability in food production.

Green revolution gave tremendous boost to food grain production and transformed the nation from a food deficit to become a food surplus nation. However, two major pitfall of green revolution are:

- Unevenness in food production progress in different commodities and ecologies
- Inadequate focus on environmental issues leading to system un-sustainability

The cereal based cropping systems which contributed mostly to the national food basket is now showing the stagnation and or decline in the productivity. The main reason behind stagnation and or declining productivity is attributed mainly due to the monotony of the system as well as the over exhaustive nature of crop sequence and huge exploitation of soil resource base coupled with imbalanced use of inputs could led to the development of several biotic and abiotic stresses (Ali *et al.* 2006). It is estimated that country needs about 345 million tons to feed the 1.5 billion populations by 2030. The production system adopted during the Green Revolution era has now pay its costs in terms of post green revolution problems *viz.* depletion of soil fertility, water resources, creation of soil salinity, water logging, resurgence of pest and disease, increased environment pollution and decline factor productivity and quality of life due to continuous over use of chemical in the form of pesticide and fertilizers. For ever growing population and requirements for other sectors land and water resources for agriculture purpose are getting scare day by day, which is a serious threat to food security.

Crop diversification can improve resilience in a variety of ways: by engendering a greater ability to suppress pest outbreaks and dampen pathogen transmission, which may worsen under future climate scenarios, as well as by buffering crop production from the effects of greater climate variability and extreme events. Such benefits point toward the obvious value of adopting crop diversification to improve resilience, yet adoption has been slow. Economic incentives encouraging production of a select few crops, the push for biotechnology strategies, and the belief that monocultures are more productive than diversified systems have been hindrances in promoting this strategy. However, crop diversification can be implemented in a variety of forms and at a variety of scales, allowing farmers to choose a strategy that both increases resilience and provides economic benefits.

Agriculture particularly in the north eastern hill region of the country has insufficient towards food grains till date. The productivity in mountainous ecosystem is generally very low as compared to the national average due to the rainfed agriculture. Most of the area is drier during winter season which is one of the major constraints towards the increasing productivity. The only way to enhance the income and productivity of the farmers is to bring suitable crop through diversification in agriculture which is directly related to water resources and development. The selection

of those crops which can have paid better price in the market will have to incorporate in the system. In addition to that growing only cereal crops vegetables and leguminous crops can further boost to the overall improvement in the system. Apart from that farmer can also choose vegetable, fruit crops and floriculture which can pay more to the resource poor farmers of the region.

2. DIVERSIFICATION: Necessities and Benefits

Diversification of cropping system generally termed as the desirable change in the existing system towards more balanced cropping system to meet ever increasing demand of food, feed, fibre and fuel etc. on one hand and maintenance of soil fertility and agro-ecosystem on the other.

Necessities of diversification:

a) Reducing risks associated with yield, market and prices

b) Arresting the degradation of natural resources and the environment

- Water Table depletion annually by rice-wheat cropping system @70 cm yr^{-1} by consuming 5000 cr. gallon yr^{-1}.
- Reducing per capita availability from 5000 m^{-3} $years^{-1}$ in 1947 to 1700 m^{-3} $year^{-1}$ in 2004

c) Attracting national goals like employment generation, self-reliance in critical crop products and for earning foreign exchange

Benefits of Crop Diversification:

- Alternative crops may enhance profitability
- Improving soil fertility by adding legumes in system
- Diversified rotations can reduce pests
- Labour may be spread out more evenly
- Different planting and harvesting times can reduce risks from weather
- Improving the nutritional security
- Value addition
- Changing market opportunities

In the agricultural context, diversification can be regarded as the re-allocation of some of the farm's productive resources, such as land, capital, farm equipment and paid labour, into new activities for value-addition and provision of services to other farmers. Crop diversification has been recognized as an effective strategy for achieving the objectives of food security, withstanding weather aberrations, conserving natural resources, nutrition security, income growth, poverty alleviation and employment generation, judicious use of land and water resources, sustainable agricultural development and environmental improvement. Diversification of agriculture may involve inclusion.

(i) Agriculture and allied activities like animal husbandry, fisheries *etc.*

(ii) Cropping pattern/system.

The basic aims of crop diversification are to improve soil health and maintain dynamic equilibrium of agro-ecosystem. It may be adopted as a strategy for profit maximization through reaping the gains of complementary and supplementary relationships or in equating substitution and price ratios for competitive products. It also acts as a powerful tool in minimization of risk in farming. Crop diversification does not only address food security and commercialization, but also makes judicious use of land, water and other resources which makes the system economically sustainable, environmentally friendly and ecologically sound. Crop diversification from lower to high value crops offer an opportunity to improve the agricultural growth, rural employment and income (Birthal, 2010). Dependence on just one crop can have grave consequences and expose small-scale farmers to unnecessary hazards. A slump in the market value for a particular crop could greatly reduce the income of the monoculture producers. Other factors, such as the weather or pests could destroy a large part of the crop, destroying the farmer. On the other hand, farmers with diversified production systems can avoid these risks, provide their families with a healthy diet and derive a whole series of other benefits.

3. STATUS OF AGRICULTURE IN SIKKIM

Sikkim, a small state in the Eastern Himalaya with almost no flat land, this entirely mountainous state has altitude range of 300 to 8598 m above mean sea level (Avasthe, 2005) constitutes 0.22 percent of the total geographical area with 0.05 per cent population of India. It has about 15.68 per cent of cultivable area out of the total geographical area of 709,600 hectares. Land distribution is skewed with 70% of small and marginal farmers (less than 2 ha) holding only about 28 per cent of the operational area and 30 per cent of other farmers (semi medium, medium and large) holding 72 per cent of the operational area. It is estimated that more than 80 per cent of the populace of the state is dependent on agriculture. The mixed type of agriculture is still at the subsistence level rather than commercial. Amongst the Himalayan states, Sikkim has the highest percentage of people living below the poverty line (36.55%) and undernourished population (57%). The lands are three to four times less efficient and can sustain only 3-4 persons and 1 head of cattle/ha/year through crop intensification and diversification as compared to 9-10 persons in plain areas to meet the caloric and protein requirements. The per capita land holding have declined vis-à-vis net cultivated area, operated area, pasture and also forests, primarily due to fragmentation of family (Avasthe *et. al.*, 2013). Thus, diversification of subsistence agriculture to high value horticulture and livestock is on the rise. Fruits, vegetables, floriculture and spice crops, other than large cardamom, are cultivated in horti-agri farming systems. Growing of horticultural crops is an economically viable and environmentally sustainable driver of socio-economic development in Sikkim. The extent of horticulture diversification has been about 39 per cent in terms of gross cropped area, 65 per cent in terms of value of crops produced and 83 per cent in terms of net income (Figure.1).

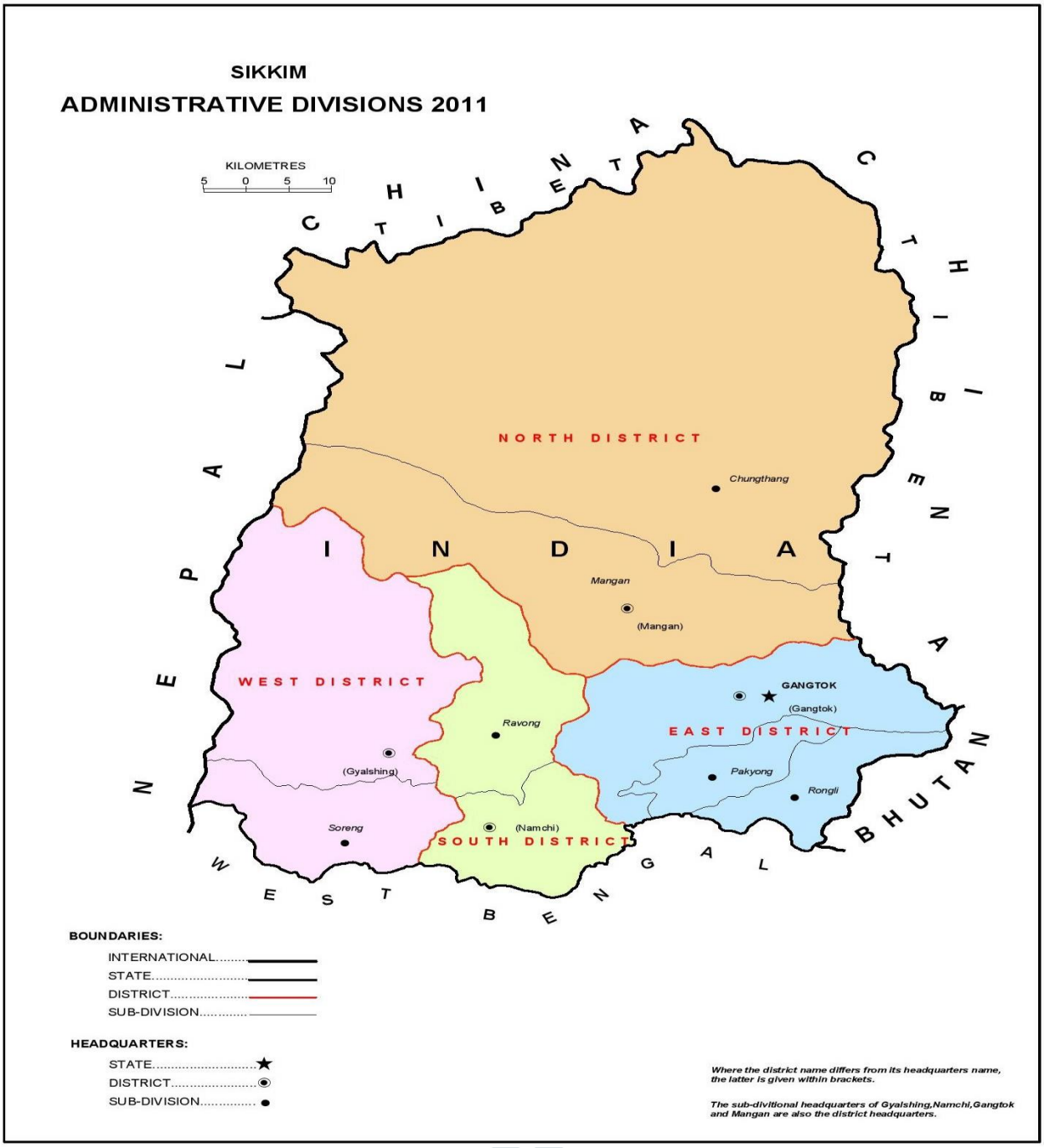

*Figure 1: Map of the study area (*Source: Census of India)

Historically, the agriculture practices in Sikkim were low input driven, however officially the State was declared organic from 2003 and has to attain fully organic status by 2015. From agriculture point of view crops are grown in three season *viz.*, *pre-kharif*, *kharif* and *rabi* season. *Pre-kharif* season starts with first showers in February when maize is sown. *Kharif* season starts from May-June in which rice, urdbean, finger millet, rice bean, beans (seed/grain vegetable), soybean and other important vegetable crops are grown. Oct-Nov is the main *rabi* season for growing crops like mustard, rapeseed, buckwheat, rayo-saag, potato, cole-crops and fenugreek, and other leafy vegetables. Apart from these crops the most important cash crops are large cardamom, ginger and turmeric which cover a sizeable area. Crops have traditionally been grown with low external chemical inputs but farmers are now adopting improved technologies in organic farming system. Although locally produced food grains and other

vegetables do not meet the requirements of the state the requirements are met from outside the state. The potential crops for organic farming system are ginger, large cardamom, turmeric, black gram, buckwheat and baby/sweet corn. In food grain crops maximum area is covered under maize, it is in *pre-kharif* season starting from February to mid of March. However, its productivity is quite low (1727 kg/ha) as compared to the national average (2250 kg/ha) (Anonymous, 2010). Rice is the next major crop after maize sown in *kharif* season. The productivity of rice is also follows the same trend like maize. The average productivity of rice in Sikkim is 1727.6 kg/ha which is quite low as compared to national average of 2125 kg/ha. Similar yield trends are also observed with other food grain crops. The basic reasons behind the lower productivity of crops are abiotic factors like low photoperiod, aberrant weather, low nutrient input and low adoption rate of agricultural technologies. Ragi and barley are grown for brewery purpose as local drinks that are very popular among the ethnic people. Soybean is consumed as fermented product. Local urdbean (Pahenlo dal, *Vigna mungo*) is very popular and covers maximum area among the pulse crops. Rajmash has gained popularity as dry pulse and its area is expanding. Rice bean and lentil is grown on a very small area in the State. During *rabi* season, rapeseed-mustard is grown by the farmers but the area is decreasing due to moisture stress. Buckwheat has gained popularity and area under the crop is increasing by replacing rapeseed-mustard.

The agriculture in the state is marred by natural calamities, low use of agri-inputs and negligible seed/variety replacement rate, geo-physical conditions, limited horizontal expansion of cultivable land, domination of a single crop, vulnerable to risk and low level of productivity, prevalence of traditional agricultural practices, diversification of crops, livestock-fish and silk exist in the region but their contribution to economic development is negligible. Degradation of prime agricultural land, over-dependence on monsoonal rains with poor irrigation infrastructure, negligible agro-processing and post-harvest management, poor transport and market infrastructure, poor monitoring and accountability of public service delivery system, remoteness of the region, high rainfall, soil erosion and high rate of leaching of nutrients, heavy infestation of weeds, insect-pests and diseases are responsible for the sluggish growth pattern and low-yielding agriculture in the region that depicts extremely grim future of agriculture in the state.

Patterns of Agricultural Diversification in Sikkim

Sikkim Himalaya represents a hotspot of agro-biodiversity. Here, agricultural diversification is picking up momentum in favour of high-value food commodities primarily to augment income rather than the traditional concept of risk management. The nature of diversification differs across regions due to existence of wide heterogeneity in agro-climate and socio-economic environments. It is interesting to delineate the key regions and sub-sectors of agriculture where diversification is catching up fast. Crops, livestock, and forestry constitute the core sectors of agriculture. The livestock sector is the principal income-generating source in agriculture followed by the crop sector. Several non-food-grain crops such as fruits, vegetables, and medicines have substituted mainly coarse cereals in the farmers' pursuit for higher income. The government-supported programmes could be promoted for the cultivation of fruits and vegetables by replacing food grains. Among others, watershed program has facilitated collection and conservation of rainwater and gave higher priority to the cultivation of fruits and vegetables. Fruits and vegetables have been the traditional route for agricultural diversification in the Sikkim Himalayan region.

Whereas fruit cultivation has been adopted in a big way in the temperate belt, the same does not appear to enjoy any comparative advantage in non-temperate belt. Moreover, the fruits being grown in the non-temperate belt are losing market to substitute fruits grown in the plains. Within horticulture, diversification through off-season vegetables seems to possess great potential in most of the areas in both temperate and non-temperate belts of the Sikkim Himalayan region. Climatic conditions in many parts of the Sikkim Himalaya are suitable to produce crops like tomato, peas, beans, cabbage, and capsicum. The price advantage makes it worthwhile to incur high production cost and transport off-season vegetables to distant consumer markets. There are many small pockets, which have attained economic progress by diversification through off season vegetables cultivation.

Spatio-temporal factors in state and agricultural diversification

Spatio-temporal factors have a great impact on the agricultural diversification in the Sikkim Himalayas. On the other hand, diversity of crops varies according to altitude and cropping seasons. Generally, crops are grown in all three altitudinal zones - valleys, mid-altitudes and high hills in two cropping seasons of *kharif* and *rabi*. Highest diversity of crops is found in the high hills during the *kharif* season. The details of agricultural and horticultural crops which may be used as diversification of the existing cropping system in Sikkim are given in Table-1.

4. OPPORTUNITIES

In making decisions about diversification farmers need to consider whether income generated by new farm enterprises will be greater than the existing activities, with similar or less risk. While growing new crops or raising animals may be technically possible, these may not be suitable for many farmers in terms of their land, labour and capital resources.

Changing consumer demand: Presently consumers possess money to spend and food consumption patterns have changed noticeably. People have moved away from a diet based on staples to one with a greater content of animal products (meat, eggs, and dairy) and fruits and vegetables. In turn, more dynamic farmers are able to diversify to meet these needs.

Changing demographics: Rapid urbanization has an impact on consumption patterns. Moreover, a smaller number of farmers, in percentage terms at least, have to supply to a larger number of consumers. While this may not imply diversification it does require adaptation to new farming techniques to meet higher demand.

Export potential: Farmers can achieve considerable success by diversifying into crops that can meet export market demand.

Value addition: This may provide an opportunity for farmers to diversify crops for value addition.

Changing marketing opportunities: Change in government policies that control the way in which farmers can link to markets can open up new diversification possibilities.

Improving nutrition: Diversifying from the monoculture of traditional staples can have important nutritional benefits for farmers.

Climate change: Existence of climatic variability will affect the cultivation of many high value crops that can be successfully grown.

Small and marginal farmers can be included in the groups for farming. This means even small and marginal farmer can practice farming on a commercial basis to generate income from their small piece of land by adoption of commodity-based cluster farming.

Table 1: Altitude wise agricultural and horticultural crops which may be used for diversification

Area	Climate	Altitude (meters)	Ecological Adaption	Major existing cropping system	Crop possibility for diversification	Horticulture crops for diversification
Lower Hills	Tropical	300-500	Irrigated and rainfed agriculture, conventiona l farming, livestock, horticulture	Maize based cropping system Maize + finger millet Maize - black gram Maize + soybean Rice based cropping system Rice –fallow-pre-*kharif* maize Rice + black gram (in bund) Rice + soybean (in bunds)	Rice, maize, black gram, smaller millets, wheat and rapeseed- mustard, pea, soybean and potato *etc.*	Cole crops, tomato, bhindi, beans, ginger, leafy vegetables, squash, guava, citrus fruits *etc.*
	Sub-Tropical	500-1500				
Mid Hills	Temper ate	1500-2000	Irrigated and rainfed agriculture, collection of minor forest produce, Horticulture	Maize based cropping system Maize - rice/soybean – potato /mustard Maize - maize + French beans (Local) Ginger + maize Maize - Finger Millet/ Rice Bean Rice - wheat/barley	Rice, maize, black gram, millets, wheat, barley, soybean, Peas, buckwheat and Potato *etc.*	Cole crops, tomato, bhindi, beans, ginger, leafy vegetables, large-cardamom, citrus fruits, plum and peach and kiwi fruit *etc.*
High Hills	Temper ate	2000-2700	Rainfed agriculture, Bhutias, Transhuma nce	Maize + rice bean – wheat Maize + wheat Rice- wheat Finger millet-wheat	Maize, barley, potato, rice bean, smaller millets	Cole crops, tomato, beans, citrus fruits, plum, peach and kiwi fruit *etc.*
	Sub-Alpine	2700-4000	Yak based – trans-humane, Pastoral Economy, Wool and Hides etc.		-	
	Alpine	4000-5000			-	
Very High Hills	Alpine	Above 5000	Lepcha grows vegetable and potato at higher elevation		-	

5. CHALLENGES

- **Urbanization**: This is both an opportunity and a threat, in that the expansion of cities places pressure on land resources and raises the value of land. If farmers are to remain on the land they need to generate greater income from that land than they could by growing basic staples. This fact, and the proximity of markets, explains why farmers close to urban areas tend to diversify into high-value crops earlier then these in the interior areas.
- **Risk**: Farmers face the risk from bad weather and fluctuating prices. Diversification is a logical response to both. For example, some crops are more drought-resistant than others, but may offer poorer economic returns. A diversified portfolio of products should ensure that farmers do not suffer complete ruin when the weather is bad. Similarly, diversification can manage price risk, on the assumption that not all products will suffer low prices at the same time. In fact, farmers often do the opposite of diversification by planting products that have a high price in one year, only to see the price collapse in the next, as explained by the Cobweb Theory.
- **External threats**: Farmers who are dependent on exports run the risk that conditions will change in their markets, not because of a change in consumer demand but because of policy changes.
- **Domestic policy threats**: Agricultural production is sometimes undertaken as a consequence of government subsidies, rather than because it is inherently profitable. The reduction or removal of those subsidies, whether direct or indirect, can have a major impact on farmers and provide a significant incentive for diversification or, in some cases, for returning to production of crops grown prior to the introduction of subsidies.
- **Transportation:** The transportation network is very weak, particularly in the hill areas. Thus, transportation of planting materials to production sites and of produce to the markets is usually difficult and expensive.

6. CONCLUSION

Climate change will affect both biotic (pest, pathogens) and abiotic (solar radiation, water, temperature) factors in crop, threatening crop sustainability and ultimately productivity. Hence, more diverse with a broader range of traits and functions will be better to perform under changing environmental conditions which is important given the expected changes to biotic and abiotic conditions. Crop diversification may be the panacea for the resources poor farmers but sound technological packages should be provided to the production area. Exportable high value commodities should be identified for each of the districts and production cost should be reduced so that Sikkimese produce can compete with those from the plains. The focus should be on priority commodities such as off-season vegetables, vegetable seeds, citrus, apple, mushroom *etc.*, which can have good markets (both domestic and external). The production pocket area should be in group/cluster approach in order to maintain their profitability.

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