Ecological Intensification of Natural Resources Towards Sustainable Productive System

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Abstract

As per the estimates of FAO (Food and Agriculture Organization) world's population would be requiring 60% more food in comparison to present times till 2050. The situation is worser due to limitation in terms of availability of arable lands. In this context, intensification in the agricultural sector is the basic requirement for both developed and developing nations. Intensification towards sustainability is an important aspect for sustainable utilization of resource and its management. Policy formulation, strategies and technological growth should take place at the scientific level and executed at the farmers level in order to reduce inputs and maximize the yield and productivity. This would also help in maintaining agro-biodiversity along with ecosystem services followed by livelihood sustenance. Therefore, innovation in the field of agroecology through incentive-based practices may give fruitful results. Ecological intensification (EI) has an integrated approach by improving production along with maintenance of environmental quality. EI addresses various issues such as food security as well as technological intervention in the form of organic farming, conservation agriculture, climate smart practices, etc. Above all it addresses the issues of environmental sustainability through proper strategy formulations, good

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M. K. Jhariya et al. (eds.), *Ecological Intensification of Natural Resources for Sustainable Agriculture*, https://doi.org/10.1007/978-981-33-4203-3_1

governance and generation of awareness for adoption of EI for economic and ecological gain.

Keywords

Agriculture · Climate change · Ecological intensification · Environment · Forestry · Sustainability

Abbreviations

EI	Ecological Intensification
EU	European Union
FAO	Food and Agricultural Organization
GHGs	Greenhouse Gases
NR	Natural Resource
R&D	Research and Development
SD	Sustainable Development
SI	Sustainable Intensification

1.1 Introduction

In the present era modernized technique and process used in agriculture is creating environmental degradation along with the loss of biodiversity. The impact is severe as it reduces the agricultural productivity as well as total destruction of agroecosystem on long term. Various factors play effective role towards agriculture and economy. Another big issue includes feeding of growing population of human beings across the world. In this context, intensification in agricultural practices is the need of the hour. But, one must take care about the process should be eco-friendly. Maintaining the harmony of natural resource (NR) is also required to maintain the integrity of agroecosystem (Kumar et al. 2020; Jhariya et al. 2019a). Therefore, intensification can be achieved in the sector of farm inputs, mechanized inputs, man power inputs as well as proper functioning of the ecosystem.

Such approaches should promote efficient and sustainable NR utilization. However, such approaches are sometimes criticized for lesser efficiency and less protection of biodiversity (Raj et al. 2018). In this context, ecological intensification (EI) focuses on sustainable functioning of ecosystem, ecological processes as well as ecological interactions (Shaver et al. 2015). To achieve sustainability in agriculture sector eco-intensive farming practices should be approached using natural assets and services within the carrying capacity of the habitat. One major problem on this aspect is practicing eco-farming technologies does not fulfil the growing demand of food worldwide (Meena et al. 2018; Harvey et al. 2014). In Indian perspective as there is gradual increase in the footprint of agroecosystem, it is creating a crisis

situation for other NRs as well as human civilization (Banerjee et al. 2020; Raj et al. 2020). Intensification of agricultural activities should therefore be properly investigated by the global scientific community.

Ecosystem is an integrated unit of biotic and abiotic factors. Therefore, efficient functioning of ecosystem is very much essential to maintain the ecosystem homeostasis. It has been observed that high level of biodiversity promotes EI in agricultural productivity and economically effective. Multifaceted of benefits lies within agricultural biodiversity such as maintenance of soil quality and nutrient flow in agroecosystem, protection and conservation of soil and water as well as the integrity of ecosystem. Loss of biodiversity in agroecosystem has revealed loss of genetic diversity as well as more susceptibility of ecosystem towards various stresses (Jhariya et al. 2019a).

To achieve sustainability, one has to work in a combined way to promote conservation of agro-diversity as well as move towards increased production. Intensification in the negative sense leads to the use of modernized technology causing agro-pollution and therefore, world is looking for suitable alternatives through eco-friendly practices. This way of deleterious agricultural practices has caused a drastic reduction in world's biodiversity at macro level. Intensive use of agrochemicals has converted the complex nature of ecosystem and species interaction into simpler forms of reduced number of food chains and food webs operating in a particular ecosystem (Meena et al. 2020). When one considers intensification in terms of agricultural productivity more than half of flora and fauna in UK has depleted due to increased cultivation practices (UNEPWCMC 2011).

The problem of biodiversity loss is a century old problem which is aggravated through modernization of agro-technology causing a crisis situation in the entire Europe along with loss of ecosystem services (Storkey et al. 2012). As a consequence of that agro-biodiversity becomes the key issue in the policy matter of European Union (EU) promoting R&D (research and development) in various schemes of agriculture and environment (Sutcliffe et al. 2015). As a consequence of that vision of EU Biodiversity Strategy-2020, focused on strengthening ecosystem function and promote sustainable development (SD) in the sectors of forestry and farming (Mace et al. 2010). It has been observed that by preserving biological diversity one can achieve sustainability in the field of agricultural production (Tryjanowski et al. 2011).

The present chapter deals with various forms of EI practices leading towards SD in agroecosystem and NR conservation.

1.2 Problems Associated with the Resources

India is an agriculture based country in which 75% of the people are dependent upon agricultural activities for maintaining their livelihood. Rest of the people is also dependent upon the natural assets in terms of consumption and habitat. The prosperity and well-being of human civilization is dependent upon the reserve base of NR along with environmental quality. In Indian perspective the major issue is that

resource depletion appears to be a common aspect reducing the quantity and quality of NR. Each of the components of the ecosystem is under threat from various forms of environmental degradation reducing the agricultural productivity to a considerable extent. For instance in the hydrosphere the ground water extraction is taking place in an unprecedented rate, water pollution in an uncontrolled way and as a consequence fresh and safe water is a scare resource (Meena and Lal 2018). Pollution in every sphere of environment hampers the productivity and economic growth of a country. However, in developed nations conservation approaches seem to be a luxury to maintain the aesthetics. On the other hand developing countries are under stress to promote such approaches for their existence (Singh 2009).

Intensification to boost up agricultural productivity has huge negative impact upon biodiversity and other associated ecosystem services. Such losses promote ecological invasion, loss of indigenous crop diversity, making more species critically endangered or rare and overall decline in agricultural productivity (Kennedy et al. 2002; Jhariya and Yadav 2017). Researches have revealed better productive agroecosystem nurtures higher level of biodiversity of flora and fauna (Tscharntke et al. 2005). Decline in avifaunal species have been reported by various researchers due to reduction in agricultural productivity (Soderstrom et al. 2001). Considering the facts the concept of sustainable agriculture emerged to maintain both the quantity and quality of food as well as promote EI process to operate within the agroecosystem in the form of organic farming, green farming, etc.

With the unprecedented growth of human population, problems of food security and crisis came into our forefront. As per the report of Food and Agriculture Organization (FAO) (2012a) more than 800 million people are suffering from the problem of food crisis along with improper diet and nutrition globally. The situation is much worser in the developing countries. It is a biggest challenge in the area of intensification and as a consequence to cope up with such problems, EI is the solution. Further, wastage of food materials is also putting pressure on the agroecosystem by increasing the demand for human civilization (Alexandratos and Bruinsma 2012; Meena et al. 2020a, b). Therefore, implementing EI is a hard task to perform for betterment of quality of life (FAO 2012b).

Agriculture comprises of diverse form of activities including crop cultivation and management of animal husbandry which provides multifaceted of economic benefits for people both in developed and developing countries. Therefore, eco-intensified agriculture can be considered as a combating measure towards the problem of food security, crisis and poverty. The major problem in terms of global economy includes growth and development of non-agricultural sectors in comparison to agricultural sectors which is prevalent in developing countries (FAO 2012a). Therefore, the objective of agriculture is not only to provide food and employment opportunities but also act subsequently to combat environmental challenges as well as with other non-agricultural sectors. Thus, a paradigm shift is required towards sustainable agriculture through capacity building and comprehensive policy framework.

Green revolution is a mega event in the area of intensification of agricultural productivity. Under this event adoption of hybrid seeds, chemical inputs and modernized technologies have intensified the agricultural productivity to a

considerable extend (Stevenson et al. 2011). Such agricultural intensification activities have also addressed the issues of poverty up to a certain level. Higher productivity would lead to decline in economy of agricultural products which indirectly contributes to socio-economic development of rural livelihoods. On the other hand agricultural intensification has promoted environmental degradation in various forms and thus has become a bane for the modern technological world. Under such situation intensification practices should be modified to EI practices.

The EI process in agriculture seems to focus on zero wastage and more production strategy. On the other hand it should encompass for socio-economic upliftment and economy of rural stakeholders. Another aspect of EI of agriculture includes developing the agroecosystem as a shock absorber under the face of various biotic and abiotic stresses. The agroecosystem should be capable of reducing greenhouse gases (GHGs) emission, providing ecosystem services such as pest and disease control along with maintenance of fertile land. The modern agriculture should also be energy intensive which will consume less energy and eco-friendly sources of energy. The major challenge would be to focus on development of such an agricultural system which reduces the negative impact on the ecosystem. Sustainable agriculture in this perspective requires an integrated approach for sustainable use of NR and efficient management of ecosystem services. In this way the negative impacts on agroecosystem can be reduced and one can move towards climate resilient agroecosystem in future. Under this purview, the focus point should be on conservation of crop varieties, climate resilient agriculture practice, maintenance of germplasm stock and proper utilization of genetic resources in terms of ecosystem services they provide.

Level of awareness and willingness of farming community towards EI activities is also required from unsustainable to sustainable practices. Further, effective implementation of policies should also be required for their better accountability. In these aspects recognizing traditional knowledge and experience of farming communities may be the better option for adopting EI practices. Economic incentives, rights over land would help the rural poor farmers to adopt EI practices in their agricultural system. Capacity building is also an important aspect in order to achieve sustainability through EI practices.

1.3 Agricultural Intensification and Environmental Sustainability

Use of NR is associated with the agricultural activities to a maximum extent. As per the reports maintenance of livestock tends to be the largest user of land on the earth surface, using 3/4th of the geographical area of cultivable land. Also, in agriculture sector >65% of water resource is usually consumed (Kabat 2013). More than half of the geographical habitat and assets are consumed unsustainably through agricultural activities (MEA 2005). As per FAO (2011b) approximately 1/3rd of food materials (>1.2 billion t/yr) are gradually wasted across the world which is severe in front of food crisis problem. By comparing the economic conditions of developed and

developing nations, it was observed that wastage of food occurs at consumer level for high income countries and loss during agricultural activities in low income countries due to the lack of proper infrastructure. Reducing the wastage of food one can minimize the food demand as well as associated cost in cultivation practices.

In the present context, sustainable agriculture is the need of the hour. It involves approaches of wide dimension such as conservation agriculture, integrated nutrient and pests management, various forms of intensification practices and technologies (e.g. system of rice intensification), region based tested model, proper management of livestock along with conservation of NRs such as water and soil (Table 1.1).

Sustainable production system has various components which include eco-friendly practices, application of agroecological principles supported by good legal framework along with proper planning, execution and monitoring process (Fig. 1.1).

EI is such a process or approach which acts upon the community level through eco-governance leading to ecosystem quality improvement followed by increase in ecological value. In this process there is growth in technological innovation leading to equilibrium between ecosystem quality improvement and ecological values (Fig. 1.2).

1.4 Challenges for Ecological Intensification towards Sustainability

Increasing productivity in an unscientific manner is creating the problem of agricultural pollution and land degradation. Intensive use of pesticides and fertilizers is increasing the energy footprint, economic cost, loss of soil health and agro-biodiversity and many more irreplaceable problems (Meena et al. 2020; Jhariya et al. 2018a, 2018b). On the other hand we have to increase the food production to feed the growing human population of the globe. Therefore, the concept of EI becomes very handy to address these problems. Further, it would also lead to sustainability.

Implementing EI at the grassroot level is very challenging as because it requires an integrated approach as well as proper scientific planning and suitable strategies. In the agroecosystem the soil and water environment is affected mostly at the cost of more production. For example, problem such as soil salinization, desertification, soil erosion are the result of faulty land-use practices. In the water component it was observed that non-judicious use of chemical fertilizer and pesticides pollute the water in the form of growth of algal blooms known as eutrophication. Another major issue is the pest and disease outbreaks within the agroecosystem which reduces the crop yield in significant level. Therefore, an approach of integration between agriculture and ecology is very much essential to overcome these challenges.

Two major challenges associated with agroecosystem includes the problem of hunger and malnutrition followed by too much of anthropogenic influence causing ecological overshoot and crossing carrying capacity of the earth. Secondary

Table 1.1 Various schemes of ecological intensification across the globe

Practices/schemes/ methods/models	Region	Outcomes	References
The comprehensive assessment of water management in agriculture (2007)	Burkina Faso alone	Rehabilitation of more than 2,50,000 hectares of land and production of more than 75,000 tons of food material annually.	Reij et al. (2009)
	Southern Niger	Farming community are actively engaged in regeneration and multiplication of trees of higher economy which has improved the land quality of more than 4.5 million hectares with extra production of 500,000 tons of food annually. This has been contributed significantly to ensure food security for more than 2.5 million people. Further economic earning increases up to >200 $ due to baobab production on household basis annually.	
	Ethiopia	Farming community is capturing the agricultural runoff from various natural structures by creating temporary water reservoir and then utilizing it for irrigation purpose. In this process it was found that >60,000 hectare land area has come under irrigation followed by benefits to over >3 lakh people due to sorghum production. It has also benefited the agricultural extension of various horticultural productions up to 3/4th times.	Binyam and Desale (2015)
Conservation agriculture (CA)	Brazil	Conservation based agriculture is practiced for >20 million hectares accounting for >20% cultivable land combating the events of drought and erosion. As per report in 2008–2009 the yield loss	Altieri et al. (2012)

(continued)

Table 1.1 (continued)

Practices/schemes/ methods/models	Region	Outcomes	References
		in production of maize almost reached half of the production. However, farmers who practiced CA reflected approximately 20% loss in maize production. This approach leads to ecosystem resilience of CA.	
	Developing countries	An average increase in yield of 79% was reflected in CA projects from pilot study of >250 projects across >50 countries of the globe. It helps to increase the water use efficiency of crops, improves C sequestration potential and reduces the dependency on pesticides for eradication of pests.	Pretty et al. (2006)
Sustainable intensification (the foresight project)	African countries	Sustainable intensification approach were adopted by >15 African countries in >35 projects with an economic benefit to >ten million farming community along with improvement in the environment up to 12 million hectare land area	Pretty et al. (2011)
System of rice intensification (SRI)	Various region of the world	SRI has been widely adopted for staple food crops along with other vegetable crops for sustainable yield. The benefit of SRI has been reflected for >45 countries with an yield increase up to 100% with 9/10th reduction in seed requirement as well as half reduction of water requirements	SRI International Network and Resources Center (2014)
	India	From Indian perspective in the past five decades development of small holds farmer were found	Vidal (2013)

(continued)

Table 1.1 (continued)

Practices/schemes/ methods/models	Region	Outcomes	References
		among the global population of 500 million. SRI such a technology which requires lesser inputs and thus become economically feasible. Bihar government is actively promoting this programme	
Participatory plant breeding (PPB)	China	The south West China, maize based PPB programme was initiated and increase in yields was recorded up to 30%. Organic supplements have increased the production of maize by 30% in comparison to villages not adopting the PPB programme and therefore promoted the economic flow towards the villages adopting PPB models. Such approaches help in regulation of pest population, use of organic amendments. Area under risks may be adapted with monocropping system to reduce the risk of crop failure, and adaptation to local condition, and was found to be more efficient in increasing the quality and quantity of yield in comparison to the hybrid variety	Song and Li (2011)
One acre fund	Western Kenya	In western Kenya till 2012 investment of *One Acre Fund* has promoted three times yield increment of raw material after harvesting with per acre of plantation. Further, the economic gain has increased twice.	Pretty et al. (2011); Royal Society (2009)
Microdosing	Niger, Mali and Burkina Faso	The microdose concept adopted in various African countries have reduced the	ICRISAT (2009)

(continued)

Table 1.1 (continued)

Practices/schemes/ methods/models	Region	Outcomes	References
		chemical fertilizer use with higher yield of millet crops along with other crops having better adoptability of water	
The zai system	Burkina Faso	The Zai approach includes seed showing through organic amendments such as leaves and compost manure along with rain water is done during summer season which enriches the soil biota. Further, sowing of sorghum and millet crop tend to increase the yield up to 120% giving additional yield of >75,000 tons grain annually	CGIAR (2011); Sawadogo (2011)
Agroforestry with *Faidherbia Albida*	African countries	Leguminous crop tend to add nitrogen through biological nitrogen fixation as well as decomposition of plant materials. Plantation of crops under leguminous tree is a suitable alternative which can give better yield without the application of fertilizers. Additionally the leguminous trees add >2 tons per hectare basis carbon into the soil and it has been reported that mature trees can add carbon up to 30 tons per hectare basis	World agroforestry Centre (n.d.) (http://www.worldagroforestry.org/sites/default/files/F.a_keystone_of_Ev_Ag.pdf)
IPM with FFS model (farmer field schools)	African countries	Under the leadership of FAO and the partnership with civil society IPM and FFS models was launched in Ghana in which training and extension programme were given to the farmers and as an outcome 23% yield increase was recorded with a decline in 75% pesticide use	FAO (2001), (http://www.fao.org/fileadmin/templates/agphome/documents/IPM/IPPM_West_Africa.pdf)

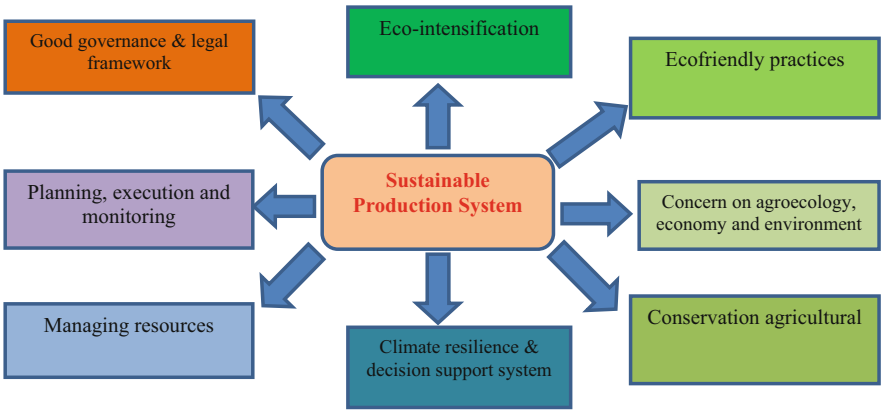

Fig. 1.1 Components of sustainable production system

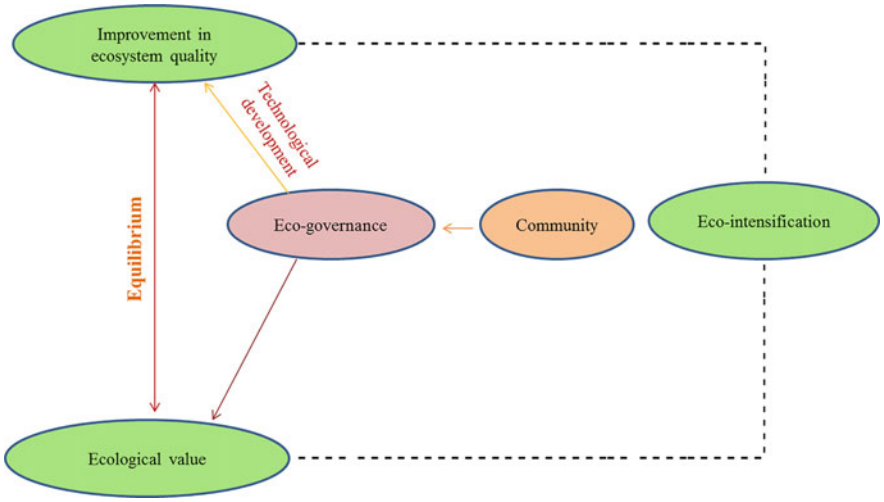

Fig. 1.2 Pathway of ecological intensification

challenge includes loss of agro-biodiversity, higher level of GHGs emission followed by rising temperature of the earth surface leading to climate change. Further, scarcity of fresh water resources, higher rate of deforestation, high concentration of nutrients are adding more challenges in the soil environment of the agroecosystem. In developing countries poverty is another biggest challenge for the agricultural sector to feed the population (FAO 2012a). Therefore, the multifaceted of challenges in agriculture is to provide nutritious and adequate food to people on one hand and mitigate environmental issues on the other (FAO 2012a).

Under the objective of increasing productivity it was observed that 60% of the ecosystem across the globe is under severe threat due to unsustainable utilization.

Further, the genetic diversity of the agroecosystem is also under threat due to the pressure of climate change, technological innovation in terms of hybrid variety introduction, followed by land-use changes. For example rapid deforestation is taking place for expansion of the agricultural land (Kabat 2013; UNEP 2010). Unequal distribution of economy and technology between the developed and developing nations often creates the problem of wastage of agricultural produce. According to one estimate given by FAO (2011b) one third of the food produced across the globe is wasted simply because of unequal distribution between the production and consumption sectors. It was observed that countries with higher and medium level of economy tend to waste food material in comparison to low economy country. Food may be wasted during the processing step, transportation or during storage.

Across the globe there is range of factors that influences the effectivity of intensification practices. Among them the most important one includes economic incentive, lack of appropriate technology, food crisis, ever increasing human population, soil and climatic conditions (Table 1.2).

Considering the present scenario of population boom followed by environmental degradation specific strategies needs to be formulated towards various components of intensification such as agricultural intensification, EI and sustainable intensification (SI). These three components have a complex interaction in order to achieve SD of human civilization. Food production is the biggest challenge for agricultural intensification, maintaining ecological health and services for EI followed by socio-economic and environmental improvement for SI (Table 1.3).

1.5 Nexus Between Intensification, Food Security and Crisis Under Changing Climate

The major challenge in front of modern world is producing sufficient food and maintaining the ecological integrity of agroecosystem. Such issues cannot be resolved through conventional agricultural practices and therefore, there is urgent need of EI. Proper management through EI is the requirement to address the issue of sustainable agriculture. To implement such strategies proper scientific knowledge, technical skills, adequate infrastructure is required to focus EI and sustainable agriculture. It was observed that the issue of food security at local level can be resolved through adoption of low input agricultural practices leading to socio-economic upliftment of local community stakeholders. This leads to development of concepts such as organic farming, biofertilizer based farming along with introduction of advance molecular techniques towards climate resilient agriculture practice (Halberg et al. 2015).

As per FAO a massive increase in agricultural output is required within 40 years span of which significant contribution should come from the under developed world, where the production of biomass needs to be increased for the said period (Alexandratos and Bruinsma 2012). Another challenge is in the form of competition to be maintained between productivity and energy production in the form of biomass

Table 1.2 Challenges of ecological intensification across the globe

Location/region	Study level	Factors influencing	References
Amazon region of Brazil	Field/farm	Accessibility and policy for marketing, commodity price, facilities for ranching, etc.	Cortner et al. (2019)
Malawi (central and southern part)	Farming community	Lack of infrastructure, high population strength, low productivity of soil, farmers response, etc.	David et al. (2016)
Malawi central region	Field/farm	Male female ratio, climatic feature, commodity price, availability of land, population strength, etc.	Snapp et al. (2018)
Andes central region	Regional	Climatic perturbations, mining and grazing activities, improper plantation, etc.	Willy et al. (2019)
Africa (eastern and southern region)	Field/plot	Extension activities, accessibility of markets, lack of information technology, technological upgradation, etc.	Kassie et al. (2015)
Kenya (eastern and western region)	Farming community	Male female ratio, lack of technology, quality of land, extension activities and accessibility of markets, etc.	Ndiritu et al. (2014)
Kenya, Uganda and Ethiopia (eastern region of Africa)	Nation	Insufficient incentives for economic growth, extension activities, improper infrastructure	Yami and Van (2017)
Uganda (eastern part)	Farming community	Lack of information technology, price variability, climatic perturbations, insufficient yield, livelihood of farming community, population strength, etc.	Rahn et al. (2018)
Kenya (eastern part)	Field/farm	Population strength, soil fertility and productivity, lack of information technology, farmer's attitude, local climatology, etc.	Rolando et al. (2017)
Germany	Field/plot	Soil edaphic features, food requirement, population strength, etc.	Schiefer et al. (2015)
Sub-Saharan Africa	Farming community	Soil quality, population strength, improper production, productivity, livelihood, accessibility to market, etc.	Vanlauwe et al. (2014)
Kenya (southern part)	Rural setup /village level	Population strength, commodity price variability, precipitation, etc.	Zaal and Oostendorp (2002)
Tropical Reunion	Field/farm	Population strength, rising food requirement, biotic and abiotic stress, nature of land, etc.	Jonathan et al. (2011)
India	–	Population rise, small land holding, subsidy for agricultural inputs, poverty level, information technology, infrastructure, soil and climatic conditions, etc.	Vidal (2013), Nath et al. (2016)

Table 1.3 Strategies for various components of intensification (Source: Tittonell 2014; Tittonell and Giller 2013; Wezel et al. 2015; Clay 2018; Xie et al. 2019)

Agricultural intensification	Ecological intensification	Sustainable intensification
✓ Intensify agricultural productivity. ✓ Greater sales and marketing. ✓ Increase productivity on region basis. ✓ Increase market share for socio-economic upliftment. ✓Environment intensive farming practices	✓ Minimizing the negative impact of modern agriculture. ✓ Maintain the soil health and biodiversity. ✓ Optimum use of resources. ✓ Ecology based processes and services. ✓ Minimizing external inputs and focusing in on-farm inputs. ✓ Maintenance of ecosystem services. ✓ Recognizing traditional knowledge for resource conservation	✓ Reduce energy subsidy. ✓ Maintain ecosystem resilience. ✓ Agricultural diversion for proper land-use. ✓ Improve economic potential and quality. ✓ Adaptation and mitigation through capacity building. ✓ Managing landscape for multidimensional services. ✓ Resource efficient technologies. Harmonization of input-output agricultural practices. ✓ Restoration of degraded ecosystem

till 2050. Higher production of biomass would lead to development of alternate energy source by replacing fossil fuels which would help to mitigate the mega event of climate change in agricultural sector. On the other hand to feed the growing human population one needs to improve the productivity at highest level without damaging the soil and land environment (Harvey and Pilgrim 2011). Another problem is the availability of land for cultivation for increasing the agricultural productivity (Raj et al. 2019a, 2019b). As per the research data, six persons to be fed from per hectare area of agriculture land globally since 2000 onwards (Cassidy et al. 2013).

As per Halberg et al. (2009) the unsustainable consumption pattern of agroecosystem and their subsequent ecosystem services creates the issue of food security. The ecosystem service and benefits are undermined through non-judicious use of chemical fertilizer and other agrochemicals altering the soil quality to a considerable extent (Meena et al. 2020). Changing climate also poses significant challenge in terms of reduction in agricultural productivity and therefore raising the issue of food security (Porter and Xie 2014). The integrated system of food security, NR depletion and climate change is creating a huge problem for prosperity and well-being of the people (Halberg et al. 2009). Thus, to address these three issues all together, EI is the need of the hour in the agricultural sector (Fig. 1.3) (Tittonell 2014).

The nature of EI depends very much upon sustainability which can be integrated as SI. SI is such a process that aims towards conservative approach to improve soil health, fertility and productivity of agroecosystem. It is also an integrated approach that includes the principles of organic farming, use of biofertilizer and bio-pesticides policies, judicious use of agrochemicals to reduce agricultural pollution and protection from pests and diseases (FAO 2011a). Such approaches also work on case to

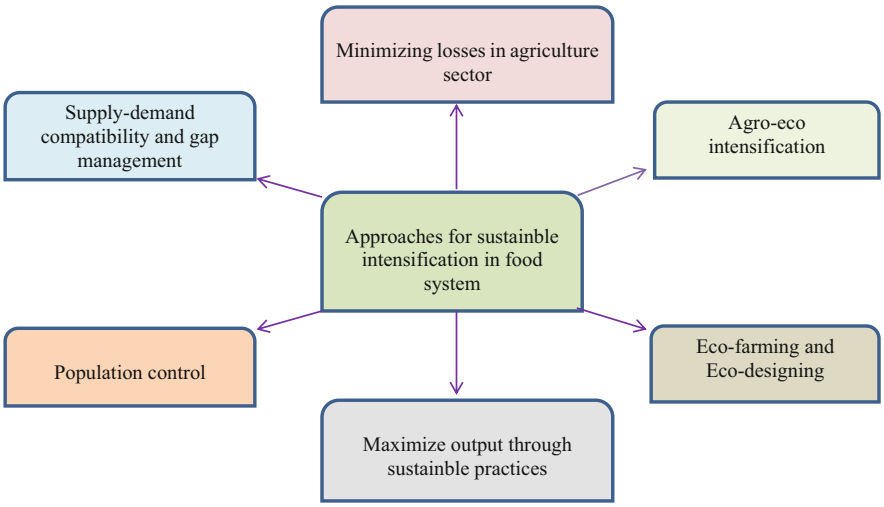

Fig. 1.3 Food production and sustainable intensification

case basis. The policy underlying the mechanism of SI includes reducing wastage of food and demand for products coming from livestock population. However, the aim of improving food production should be continued in an eco-friendly way in order to maintain the balance of the environment. In Europe the major policy behind such factor includes not only to restrict the use of agrochemicals in order to check the pollution but also towards the optimum use through intensive management for proper caring of ecosystem services provided by the agroecosystem to human civilization. In order to do that proper knowledge for specific areas needs to be maintained.

EI is a concept which emphasizes the maintenance of crop biodiversity in order to achieve sustainable yield and reduce the impact on environment (Bommarco et al. 2013). As per the various works and reports, the principle of EI is very much similar with agroecological perspective and organic mode of farming (de Abreu and Bellon 2013). Agroecology is a concept which integrates the application of ecological principles in agroecosystem for increased income for the rural stakeholder as well as maintains the ecosystem health (de Abreu and Bellon 2013). Organic agriculture is a form of cultivation practice that emphasizes more on organic inputs in order to maintained agroecosystem health and diversity. Further, it also aims towards low input agriculture practice in terms of different agrochemicals to maintain the soil health and fertility. Such system also emphasizes the use of traditional knowledge to get sustainable yield by application of modern scientific principles.

Thus, the two concepts of agroecology and organic farming emphasizes on proper maintenance of ecosystem services as well as sustainable NR utilization. Therefore, the practice of organic farming should be intensified in order to build the soil nutrient pool and organic matter. In Europe, the concept of EI was modified to eco-functional intensification by recognizing the traditional knowledge based on biological

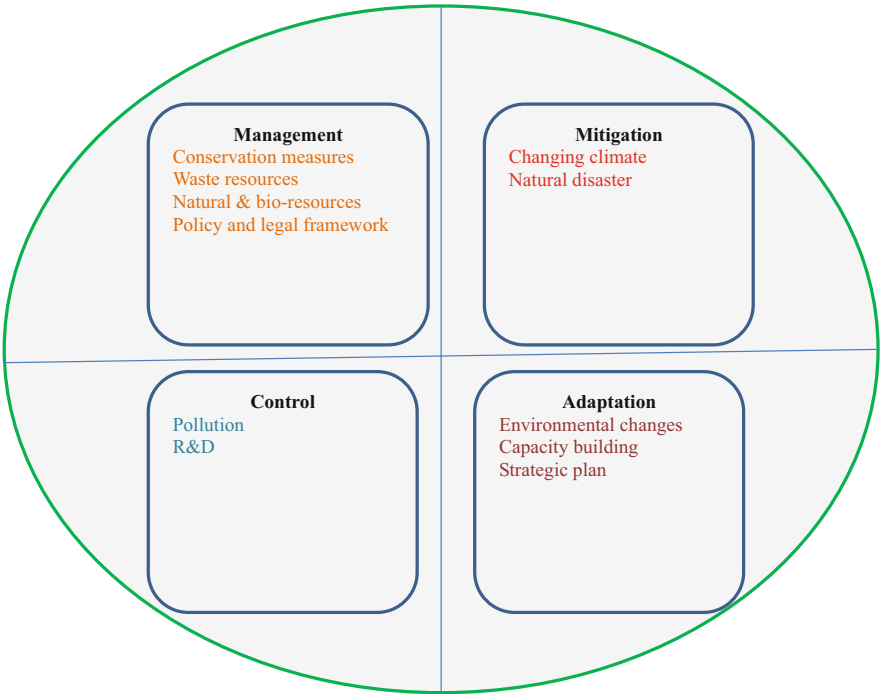

Fig. 1.4 Strategic component of ecological intensification

principles and maintaining the harmony between food production unit and agroecosystem. In this way through low input agriculture practice helps to implement eco-functional intensification principles at the field level (Lipper et al. 2014).

Strategy for implementing intensification in agricultural system comprises of management, mitigation, adaptation and control (Fig. 1.4). Management component comprises of development of policy for proper management of resources followed by effective legal infrastructure through good governance. Mitigation should be aimed towards reducing the impact of natural hazards and adopting towards climate change (Khan et al. 2020a, 2020b). In the adaptation component one needs to cope up with environmental changes followed by framing strategic plan for capacity building of stakeholders. Control components should be aimed towards pollution regulation and future R&D.

1.6 Organic Farming Towards Ecological Intensification

Field based studies were conducted by various researchers by using various combination of organic and conventional farming system to achieve the goal of EI. According to de Ponti et al. (2012) organic farming gives lesser output (1/3rd) in comparison to traditional agricultural practices across various centuries of the

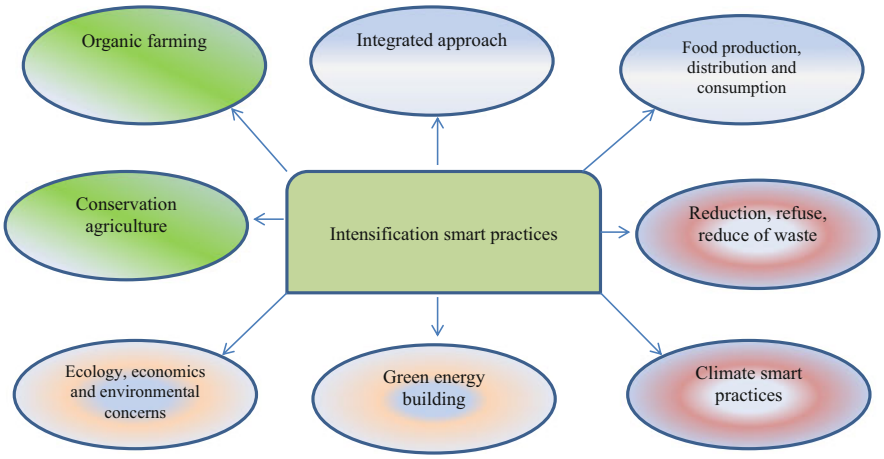

Fig. 1.5 Practices for moving towards smart intensification

globe. However, the result of the yield varies on the basis of agroecological region. For instance in Asian subcontinent yield ranges up to >80% and in European continent it is <80%. It also varies according to various crop species. But some results shown by Te Pas and Rees (2014) revealed higher output in organic farming in comparison to traditional agricultural practices under tropical and sub-tropical conditions.

Based on the type of crop the result in terms of yield also varies significantly. For example, yield gap between conventional and organic farming practices is not very significant in case of leguminous crops but the case is different for categories of non-leguminous crops (Ponisio et al. 2015). Various treatments of chemical fertilizer did not show any significant impact over yield variations. Considering these facts various diversifying practices are required in which the concept of agroecology and organic farming should be included in order to move towards EI and sustainability in agricultural system (Fig. 1.5).

According to Kirchmann et al. (2008) the level of organic farming should be upgraded in such an extent that the yield becomes comparable to conventional system of agriculture practice. The organic farming should be integrated with proper crop rotation as well as use of green manuring. This would provide continuous nutrient flow into the agroecosystem an aid in EI process. One of the major problems in relation to reduction in yield includes pest and disease outbreak which can be regulated through biological diversification of agricultural crops. This would help to maintain the soil fertility as well as soil physical properties. It also helps to build up ecosystem resilience against climate and human perturbations. However, the results seem to be little bit unclear as most of these approaches were conducted on experimental basis and the practices such as intercropping, crop diversification were not included in the field trials. There are also lacunae in terms of yield calculation

considering monocrop or yield obtained from diversified agroecosystem (Kremen and Miles 2012).

Agroecological principles are well documented giving sustainable yield under tropical condition in comparison to agricultural system of temperate region. According to a research report, in the area of east Africa *Push Pull System* of maize (*Zea mays*) intercropping was found to be promising than the conventional system in terms of yield (Altieri et al. 2012). Further development of agriculture based forestry system popularly known as agroforestry was found to be fruitfull to give higher yield by addition of nutrients in the soil through litter deposition and their subsequent decomposition (Akinnefesi et al. 2010; Jhariya et al. 2019b). This was further supported by the findings of Akinnefesi et al. (2010), who reported higher yield under the combination of fertilizer tree and half nitrogen and phosphate fertilizer in comparison to sole fertilizer application. These provide added advantage of weed control as well as improve the water and nutrient uptake by crop plants (Malezieux et al. 2009). Beside the aforesaid matter of EI approaches one need to take care about fulfilling the biomass requirement, maintaining ecosystem services as well as mitigating and adopting climatic perturbations.

1.7 Research and Development

It is no doubt that EI appears to be need of the hour considering deteriorating conditions of agroecosystem under the light of environmental pollution and climatic change. The major objective of EI includes sustainable yields along with reducing anthropogenic inputs through organic materials. Such approach would also help to regulate and maintained the ecosystem services of agroecosystem. Future research should be aimed to mitigate the gaps in sustainable yield and incorporate ecosystem services to crop production system (Bommarco et al. 2013).

A lot of work has been done in the area of food security with the help of agroecological process and eco-functional intensification. But, major problems associated with this include recognizing and evaluating the actual potential of food production to meet the present and future food demand and their proper prediction. World research has revealed the promotion of agroecological practices that would help to satisfy the growing food demand up to 2050. The proper outcome of EI at regional and global level is yet to be explored properly and therefore, demand future R&D followed by approaches and awareness (Fig. 1.6). The factor of diet preference should also be considered in relation to global food security issues (Halberg et al. 2015).

The integration of agroecology, organic farming and EI has revealed positive output in terms of agricultural output and providing ecosystem services. Therefore, the principles of agroecology and organic farming are the pillars of EI process which relies on zero chemical use for crop production. Future research needs to be done on the area of combination treatment development including organic and agroecological principles to achieve sustainability and develop ecosystem resilience. To achieve this, such practices should be followed in a wider landscape in order to maintained

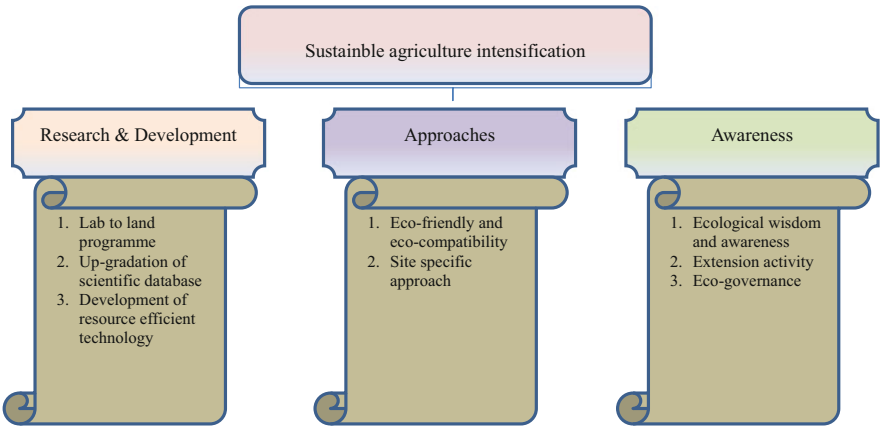

Fig. 1.6 Agroecology—a way towards ecological intensification

agro-diversity and proper land-use for moving towards sustainable agriculture (Halberg et al. 2015).

Systematic and scientific exploration needs to be done in the area of organic farming, agroecological practices and other strategies that increase crop production in a coordinated system to check or arrest the environmental degradation. These would lead to precise information for the farming community in developing nation regarding the benefits of eco-functional intensification as well as ecological sustainability in agroecosystem (Halberg et al. 2015).

1.8 Policy Intervention

Technological intervention through proper policy formulation is the requirement for successful implement of EI practices. Under such circumstances the issue of sustainability in the area of productivity and yield should be addressed in a proper way for mitigating changing climate. In this direction, one should give due consideration about the compatibility and adaptive capacity of the ecosystem in order to get maximum benefits. Further, such approaches can be promoted through upgradation of existing agro-technology and its successful adoption of local farming community. Various exogenous inputs should be minimized in order to check environmental degradation and promote EI. Such approach would lead to proper management of NR and its conservation. Another major aspect in implementing EI includes development of proper land-use policy for maximizing production in one hand and prevents deterioration of soil resource on the other (Fig. 1.7).

As the time progresses the problems or challenges are gradually becoming more complex. Demand for food, fodder, fibre and other agriproducts is increasing day by day and therefore, the agroecosystem needs to be more productive with minimum wastage. Further, to address the issue of poverty, hunger and malnutrition policies

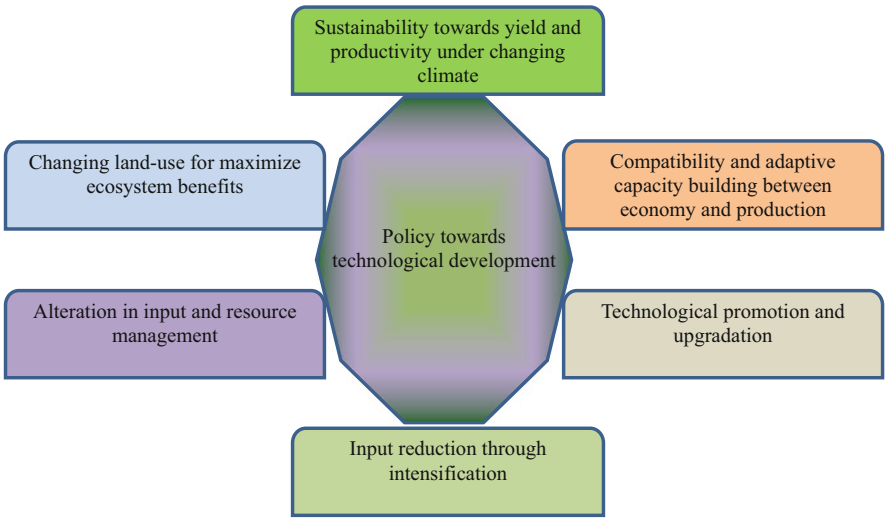

Fig. 1.7 Policy intervention towards intensification

needs to be designed to provide more income opportunities for the farming community, focus on landless farmers and labour and socio-economic upliftment from rural perspective. Another key policy should be sustainable utilization of NRs as well as strategies for mitigating climate change. From the pollution perspective reducing the GHGs emission and maintaining other ecosystem services is the essential requirement. One needs to formulate policy to design eco-friendly technologies with less energy requirement along with proper economic incentive.

1.9 Prospects of Ecological Intensification

The interaction between food production, environmental setup and agricultural practices has originated the concept of SI. The concept of SI is adopting the traditional practices such as conservation agriculture, organic farming, etc. while having major focus on reducing their deficiencies to maximize the output in a sustainable way (Blumenstein et al. 2018). The main motto behind such approaches is to develop scope for maintaining ecological integrity and ecological services. This includes a transfer of technology of normal cultivation practices to intense cultivation practices but in a sustainable way. The success and effective implementation of intensification governs the future prospects of EI. In order to do that one needs to go for model construction and its further analysis. Repeated monitoring of intensification practices across various countries needs to be done regularly on case study basis. However, there are some factors which regulate the technology and practice in the crop production system and effective implementation of intensification. This

includes socio-economic conditions followed by farmer's inherent nature to adopt intensification and play of nature.

The concept of SI includes various methods and technologies which need to be explored properly in order to increase the food production in a sustainable way. This is a big problem for effective implementation of SI (Petersen and Snapp 2015). In European countries major stress has been given on SI including the diverse disciplines and multidisciplinary approach. Further, it was observed that inclusion of economics and social sciences was not included properly in the intensification process making it questionable in terms of its cost effectiveness (Weltin et al. 2018). In many areas SI is a simply a concept of discussion but there is no proper guidelines or principles to implement them on case to case basis (Petersen and Snapp 2015). Therefore, to reveal the concept at global level there should be some suitable standard and principles on the basis of which measurement of the effectivity of the SI system can be measured. However, more robust method and principles along with scientific exploration is required in this field to develop a sound base in SI.

1.10 Future Roadmap

Green revolution has helped to increase the productivity to a considerable extent of Indian agriculture. Increase yield and productivity in Europe is associated with higher amount of environmental and economic consequences and on the other hand it has little to do with the issue of food security globally. In this context, Africa show the path of EI in cereals production associated with lesser pollution and economic loss. Another roadway includes optimum production of food depending upon the demand and in case of surplus food it would be economic revenue for farming stakeholders.

In this approach we need to formulate to identify and recognize traditional knowledge and customs for food production which indicates towards lesser input based agriculture. In relation to technology based solution on market economy, private sectors tend to opt for newer technologies and products to get more economic benefits which are their business principles. Such approach should be adopted by the public sector to have more focus on new processed technology as well as give due consideration of eco-intensifying the agricultural outputs.

Future roadmap for EI relies on various factors such as R&D activities in proper direction, designing and formulation of suitable strategies to boost the agro-economy, critical analysis of policy, strategies and technologies formulated along with subsequent evaluation and timely monitoring. In the R&D sector proper exploration should be done in the areas of agriculture intensification, EI and overall SD. Policy designing and formulation includes eco-friendly approach development through eco and green designing. Critical analysis of these strategies must include social, economic, environmental and ecological dimensions. The scale of evaluation should be broader considering the agroecosystem component, followed by legal framework and e-governance (Fig. 1.8).

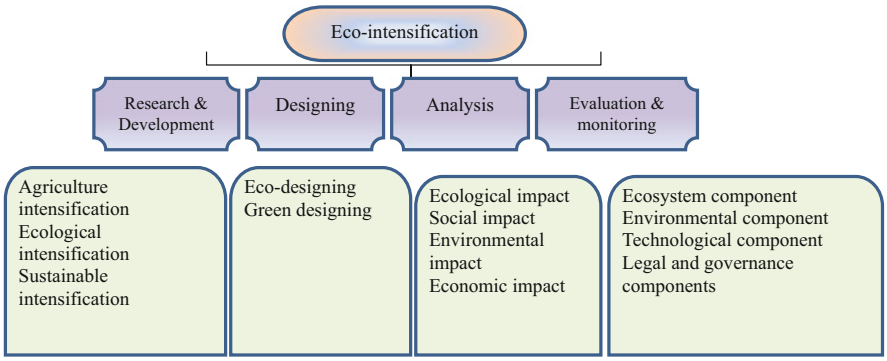

Fig. 1.8 Future roadmap for ecological intensification in sustainable agriculture

The various challenges associated with effective implementation of EI includes maximizing productivity, reduce yield gap, optimum utilization of resource and reducing environmental degradation. On the secondary part it would boost up the economy of rural stakeholders and would promote employment opportunities. Issues such as maintaining ecosystem services, arresting biodiversity loss, reducing various footprints in agroecosystem should be the future pathway for EI approaches. Overall, mitigating food security can be addressed through maintaining nutritional value and giving more emphasis on sustainable production of food. Developing the resiliency in agroecosystem is the need of the hour which would automatically address the issue of food crisis and security as well as developed mitigation attitude among the agroecosystem towards various biotic and abiotic stresses. For effectivity of eco-intensive mechanism public participation in the direction of sustainable agriculture should be promoted as well as economic incentives should be given to the rural livelihoods for their better responsiveness in the EI approaches. Use of advance technologies such as remote sensing and geographical information system could be effectively utilized to stimulate crop productivity and yield, planning and management of various resources. Promote collaboration at various levels to address the issue of sustainability in resource use and capacity building among the community is the pathway to promote EI.

Future perspective of EI comprises of appropriate steps which includes exploration of new technology, newer site inventorization, environmental quality improvement, management of NRs development of energy efficiency and efficient designing and infrastructure development (Fig. 1.9).

1.11 Conclusion

In the modern world, maintaining ecological integrity is a bigger challenge due to population explosion, climate change, increase food production, maintenance of agro-biodiversity and above all environmental degradation. Resource depletion is

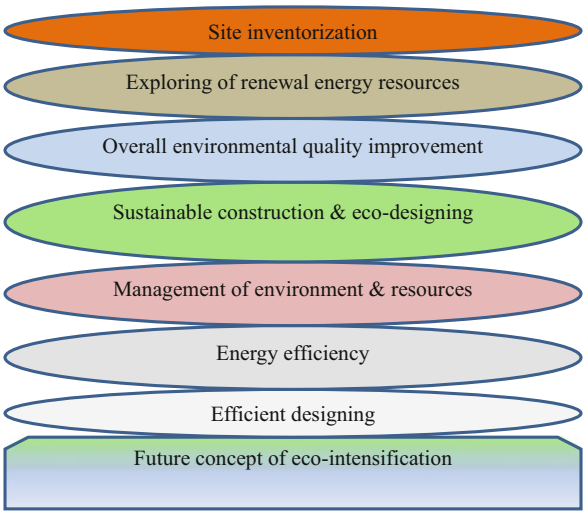

Fig. 1.9 Future perspective of ecological intensification

a significant problem in this aspect. Agricultural intensification should be kept in harmony with environmental sustainability. It, therefore, faces some severe challenges which needs to be monitored and must address the inter-relationship between food security and crisis under changing climate. Technological intervention in terms of organic farming and other such practices needs to be implemented to intensify the agricultural production. Proper research and development is the requirement of the hour for proper policy framing to move towards a greener future.

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