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Conservation agriculture, biofertilizers and biopesticides: A holistic approach for agricultural sustainability and food security: A review

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Abstract
In India intensive farming practices yield high product for which chemical fertilizers are used but these fertilizers are nowadays found harmful because they are creating environmental problems and also they are very expensive. Extensive uses of chemical fertilizers have adverse effects on human health. Dependence on chemical fertilizers and chemical pesticides for the future agricultural growth will result in further loss of soil quality, acidification of soil possibility of ground water contamination and hence loss of ecological balance. These chemical fertilizers and chemical pesticides that are sprayed on vegetables and fruits poses toxicity to the human body. Recent advancement in the field of bio- fertilizers are creating growing level of interest because these fertilizers are use environment friendly and are helping in having sustainable agricultural practice. These bio-fertilizers use living microorganisms that establishes symbiotic relationships with the plants or are an inoculation of microorganisms which promotes the plant growth by increasing the primary nutrient supply to the host plant and also retains the soil fertility. Similarly in the use of chemical pesticides many disadvantages are associated with it like the genetic changes in plant populations, food poisoning and other health problems and has made the bio-pesticides to come in the picture which might reduce the use of these chemical pesticides. Application of *vermiwash* gave 60, 10, 26 and 27% higher yield in Knol Khol (211.67qha^{-1}), onion (177.81qha^{-1}), French-bean (16.3qha^{-1} seed yield), Pea (16.3qha^{-1}) and Paddy (28.45qha^{-1}), respectively over control. Panchagavya 6 per cent spray recorded significantly higher Capsicum fruit yield (30.25, 37.49, 48.91, 118.91, 96.15, 86.29, 47.81 q ha^{-1} at 60, 70, 80, 90, 100, 110 and 120 DAT, respectively), N-fixers life (23.68, 25.59 at 60 DAT and 17.77, 17.18 X 103 at harvest during *kharif* and summer, respectively).
The exploitation of beneficial microbes as a biofertilizer has become a paramount importance in agriculture for their potential role in food security and sustainable productivity. The eco-friendly approaches inspire a wide range of application of plant growth-promoting rhizobacteria (PGPRs), endo- and ectomycorrhizal fungi, cyanobacteria, and many other useful microscopic organisms. The interactions of these beneficial microbes with environment determine crop health in natural agro-ecosystem by providing numerous services to crop plants thus enhancing soil fertility and maintaining soil heath in eco-friendly manner. Among the major environmental concerns in the world today, contamination of mother’s breast milk through the excessive and injudicious use of agrochemicals is a grave threat to humankind. It has occurred due to the paradigm shift in agricultural practices from conventional natural products to anthropogenic chemicals as fertilizers to sustain the food demand of a rising human population. Though chemical pesticides could contribute substantially to modern agricultural production systems, they alter the ecological balance and an unintended effect of that is irrevocable harm to humans and other species. Ensuring environmentally sound and sustainable crop production without causing detrimental effects to biodiversity, therefore, is the most significant challenge for humankind in this century. The potential of bio-pesticides and bio-fertilizers in promoting sustainable agriculture has been evidenced in recent years. The demand for organic farming products is expected to escalate globally in the near future, as they are a cost-efficient and renewable source for sustainable agriculture. Integrated pest management (IPM) and integrated nutrient management (INM) are two key driving forces for bio-pesticides and bio-fertilizers.

Keywords: Biofertilizer, soil fertility, ROP productivity, nutrition security

Introduction
The World population is now 7.6 Billion and India alone contains 1.35 Billion people, which is increasing day by day. This imparts pressure on the agricultural lands and other resources which are needed for food of this huge population.

According to 15th Census of India in 2011, the population decadal growth of 17.64% was observed of which around 68.84% is rural population. This growing human population demands conventional agriculture to meet its needs of food which makes farmers to depend on usage of chemical fertilizers and pesticides for increased productivity (Santos *et al*. 2012) [40]. Harmful effects of usage of such fertilizers include weakening of roots of plants, increase of disease incidence, soil acidification (Chun-Li *et al.* 2014) [6] and eutrophication of ground water and other water bodies (Youssef and Eissa, 2014) [48]. Such chemicals will have a great impact on the future generations. In this regard, eco-friendly approaches are gaining popularity with a view of bio-safety of which bio-fertilizers play a major role in sustainable agriculture. Bio-pesticides and bio-fertilizers are two important cornerstone needs intensive research to improve the quality primarily to achieve food security for the growing population and restore soil fertility. The development of new bio-pesticides with multiple mode of action against pests and bio-fertilizers with multi-crop growth promoting activities are most important for sustainable global agriculture and food security.

Challenges arising from global economic and population growth, pervasive rural poverty, degrading natural resources in agriculture land use, and climate change are forcing ecological sustainability elements to be integrated into agricultural production intensification. The situation has been exacerbated by the fact that the quality and direction of the dominant, tillage based, agricultural production systems worldwide, and the agricultural supply chains that support them, have moved dangerously off course onto a path of declining productivity and increasing negative externalities (Foresight, 2011) [12]. This path is considered to be unsustainable ecologically as well as economically and socially, and is being driven by the consequences of unquestioned faith and reliance on the dominant 'industrialised agriculture' mentality of technological interventions of genetics and agrochemicals in tillage based agriculture (Kassam, 2008) [22].

This version of agriculture, whether industrialised or not, in which the soil structure, soil life and organic matter are mechanically destroyed every season and the soil has no organic cover, is no longer sufficiently adequate to meet the agricultural and rural resource management needs and demands of the 21st century. The future requires farming to be multifunctional and at the same time ecologically, economically and socially sustainable so that it can deliver ecosystem goods and services as well as livelihoods to producers and society. Farming needs to effectively address local, national and international challenges. These challenges include: food, water and energy insecurity, climate change, pervasive rural poverty, and degradation of natural resources.

It is now clear that the root cause of our agricultural land degradation and deceasing productivity–as seen in terms of loss of soil health–is our low soil carbon farming paradigm of intensive tillage which disrupts and debilitates many important soil mediated ecosystem functions. The decrease in soil carbon due to tillage occurs even more rapidly in the tropics due to higher temperatures compared with temperate zones. For the most part our soils in tillage based farming without organic surface residue protection are becoming de-structured, our landscape is exposed and unprotected by organic mulch, and soil life is deprived of habitat and starved of organic matter. Taken together, this loss of soil biodiversity, increase in soil organic matter decease, destruction of soil structure and its biological recuperating capacity, increased soil compaction, runoff and erosion, and infestation by pests, pathogens and weeds, reflect the current degraded state of the health of many of our soils globally (Montgomery, 2007).

Further, the condition of our soils is being exacerbated by: (a) applying excessive mineral fertilisers on to farm land that has been losing its ability to respond to inputs due to degradation in soil health, and (b) reducing or doing away with crop diversity and rotations due to agrochemical inputs and commodity based market forces. The situation is leading to further problems of increased threats from insect pests, diseases and weeds against which farmers are forced to apply ever more pesticides and herbicides, and which further damage biodiversity and pollute the environment.

Soil microorganisms are solely responsible for nutrient cycling. Around 50% of soil organic matter is composed of carbon, while the rest consists of N, P, S, and other nutrients. In addition to the decomposition of soil organic matter, microbes also make chemically fixed nutrients, such as phosphorus (P), zinc (Zn), potassium (K), and iron (Fe) available. The main mechanism in the solubilization of P, K, Fe, and Zn is the lowering of pH from the production of organic acids (Jennings, 1994) [19]. The P solubilizing soil bacteria include free living rhizobacteria, such as *Pseudomonas*, the symbiotic nitrogen fixers (rhizobia), and asymbiotic nitrogen fixers (Azotobacter). In addition to release bound P through phosphatase production and rhizosphere acidification, these bacteria also provide phytohormones to crop plants and protect plants from various diseases through synthesizing siderophores, antibiotics, cyanogenic compounds, etc. (Khan *et al*., 2013) [23]. Soil bacteria and fungi have ability to reinstate soil fertility of degraded lands by improving nutrient bioavailability through nitrogen fixation and solubilization of P, K, and Fe, and aggregate satbility (Rashid *et al*., 2016) [37].

At present, one of the new challenges of the new millennium is to obtain more and more agricultural food production from shrinking per capita arable land. Biofertilizers have important and long term environmental implications, negating the adverse effects of chemicals. At the farm level, the gains from increased usage of technology can spill over to other farms and sectors through lesser water pollution than chemical fertilizers and to an extent even organic manures can be created. The gains from the new technology coming through the arrest of soil damage may not be perceived over a short span of time, unlike chemical fertilizers, which yield quick returns. Liquid bio-fertilizers are special liquid formulations containing not only the desired microorganisms and their nutrients but also special cell protectants or chemicals that promote formation of resting spores or cysts for longer shelf life and tolerance to adverse conditions.

Biofertilizers play a very significant role in improving soil fertility by fixing atmospheric N, both, in association with plant roots and without it, solubilise insoluble soil phosphates and produces plant growth substances in the soil. Biofertilizers have emerged as potential environment friendly inputs that are supplemented for proper plant growth. They hold vast potential in meeting plant nutrient requirements while minimizing the use of chemical fertilizers. These, bio-inputs or bio inoculants, which on supply to plants improve their growth and yield, are the products containing living cells of different types of microorganisms which have an ability to mobilize nutritionally important elements from non-usable form through biological stress (Mazid *et al*., 2012a) [24].

Trivedi *et al*. (2017) [46] observed that the expansion of conventional agricultural practices to meet future demands is neither economically nor environmentally feasible. There is an urgent need for complimentary approaches to sustainably meet the global food security demands. One way to develop improved and advanced sustainable crop production method is to enhance the beneficial plant-associated micro-biome. Microbes have the potential to increase crop growth and vigour, nutrient use efficiency, biotic/abiotic stress tolerance and disease resistance (Fig.1). If this potential can be harnessed under real conditions, it could improve farm productivity and food quality in a sustainable manner, leading to positive environmental, social and economic outcomes.

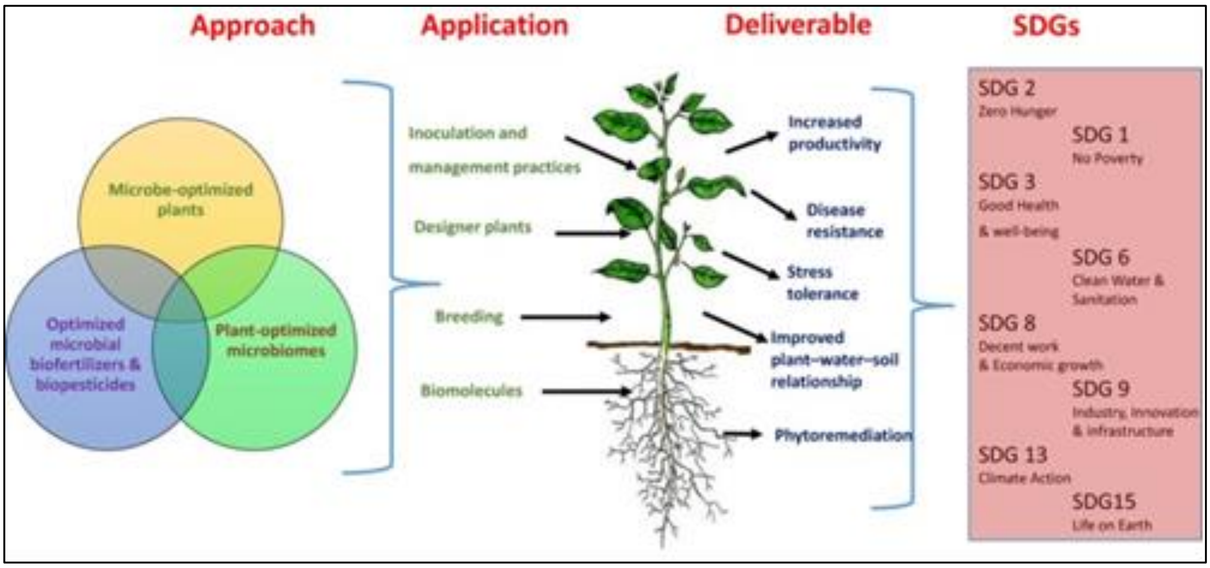

Fig 1: Sustainable increase in farm productivity by harnessing microbial technologies

Pérez-Jaramillo *et al*. (2016) [34] reported that microbial products can increase crop yields and have potential to complement or replace agricultural chemicals and fertilizers. However, an increase of 10–20% in crop production on economically important crop plants. Gopal and Gupta, (2016) also found that the synthetic microbial communities can be successfully used to provide benefits to the plants in terms of early flowering, nutrient acquisition and disease resistance.

Kachhawa, (2017) [20] revealed that the use of microorganisms as bio-pesticides is an environmentally friendly approach, as these microbes are very specific to their host pathogens. They could decrease agrochemical use, helping to foster environmental sustainability by reducing the harmful effects of toxic chemical compounds [Fig. 2]. Under diverse environmental conditions, there are large fluctuations in microbial communities in the rhizosphere, influenced by plant species, soil moisture and temperature regimes, environmental conditions and soil physiochemical conditions (Galazka *et al*., 2017) [13].

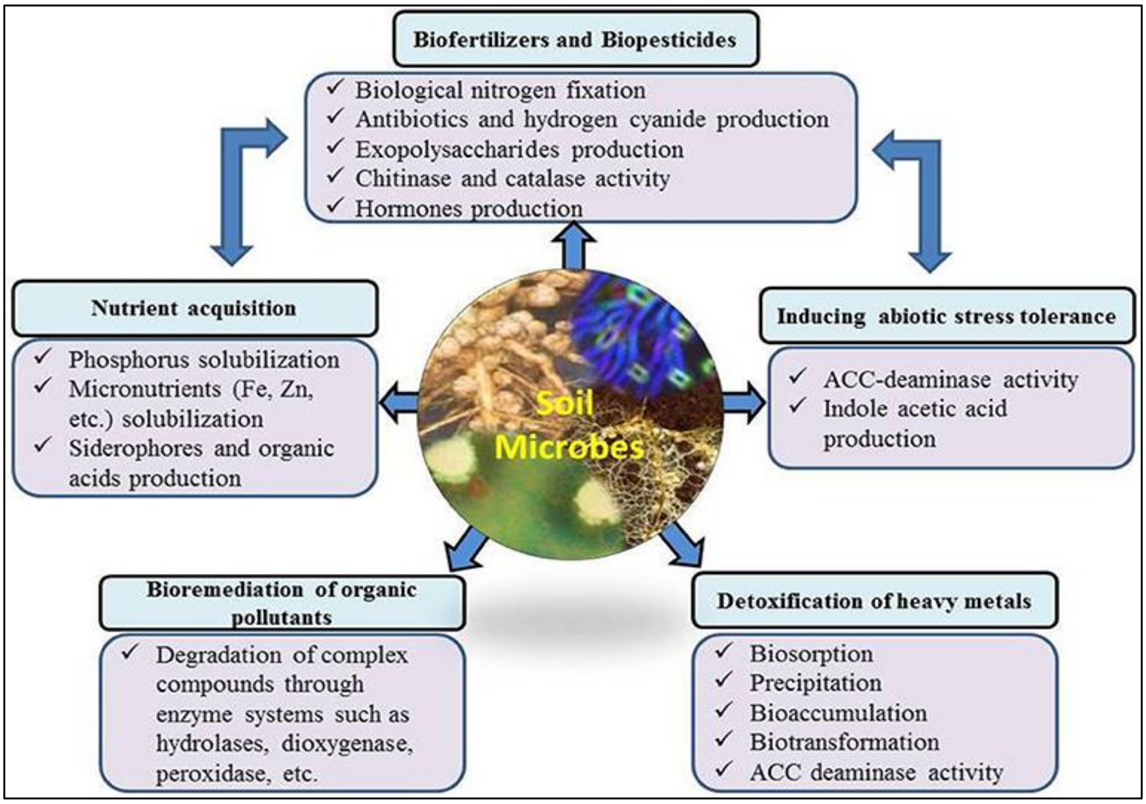

Fig 2: Importance of the microbial community for environmental health and possible mechanisms of action.

Gałazka and Grzadziel, (2018) [14] reported the fungal genetic diversity and community level through physiological profiling of microbial communities in the soil under long-term maize monoculture. They reported that techniques of maize cultivation and season had a great influence on the fungal genetic structure in the soil. These fluctuations in soil and environmental conditions also induce or suppress different plant growth promoting characteristics of microbial/strains.

Conservation Agriculture a Holistic Approach for Agricultural Sustainability and Food Security

India's nutritional and health challenges are likely to be compounded in the coming decades through population growth and resource pressures. Its current population of 1.26 billion is projected to increase to 1.6 billion by 2050, overtaking China as the world's most populous nation (UN Population Prospects 2015) [47]. India has also been highlighted as one of the most risk-prone nations for climate change impacts, water scarcity, and declining soil fertility through land degradation (Roberts, 2001) [38]. 'Intensive cultivation of land without conservation of soil fertility and soil structure would lead ultimately to the springing up of deserts. Irrigation without arrangements for drainage would result in soils getting alkaline or saline. Indiscriminate use of pesticides, fungicides and herbicides could cause adverse changes in biological balance as well as lead to an increase in the incidence of cancer and other diseases, through the toxic residues present in the grains or other edible parts. Unscientific tapping of underground water would lead to the rapid exhaustion of this wonderful capital resource left to us through ages of natural farming. The rapid replacement of numerous locally adapted varieties with one or two high yielding strains in large contiguous areas would result in the spread of serious diseases capable of wiping out entire crops, as happened during the Irish Potato Famine of 1845. Therefore, the initiation of exploitative agriculture without a proper understanding of the various consequences of every one of the changes introduced into traditional agriculture and without first building up a proper scientific and training base to sustain it, may only lead us into an era of agricultural disaster in the long run, rather than to an era of agricultural prosperity.'

Sustainable agricultural development is agricultural development that contributes to improving resource efficiency, strengthening resilience and securing social equity/responsibility of agriculture and food systems in order to ensure food security and nutrition for all, now and in the future.

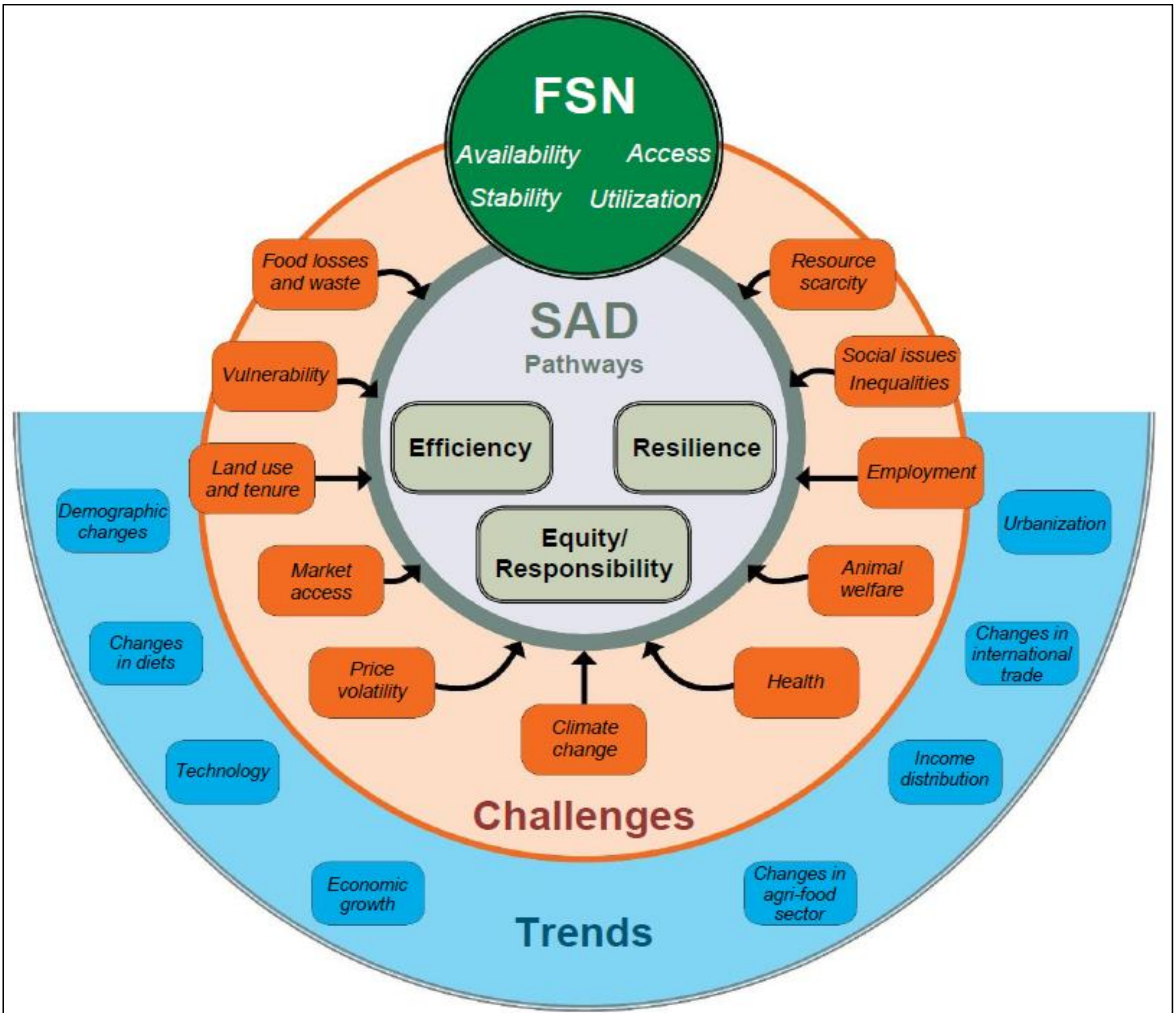

Fig 3(a): Conceptual framework: relationship between sustainable agricultural development and food security and nutrition

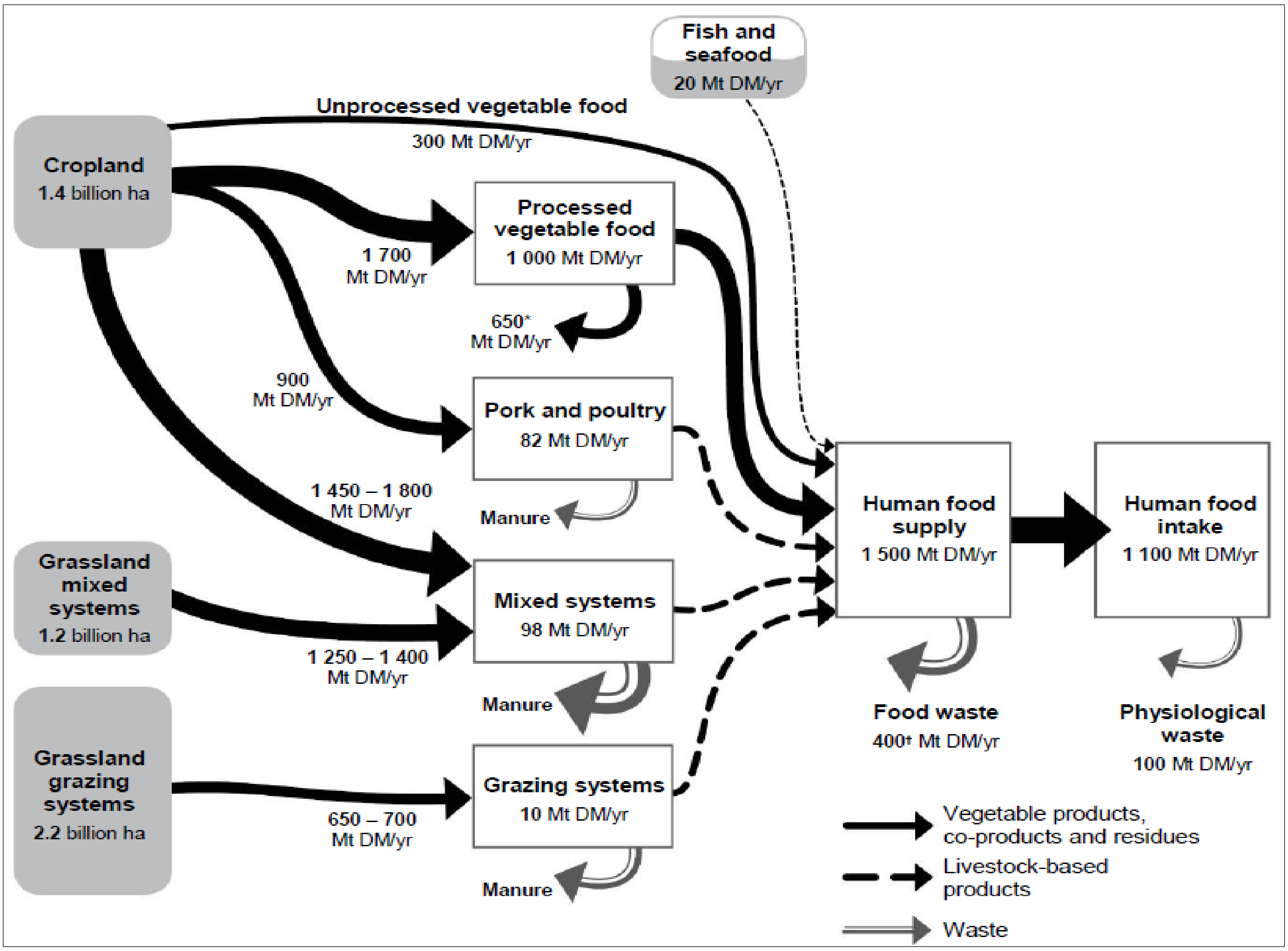

Fig 3(b): Land-use and major flows of biomass and its derivatives in the global food and agriculture system (Herrero *et al.*, (2015) [17].

Agriculture systems, being heavily resource-intensive, interact with natural resources and environment at a large scale. Around 50 per cent of India's total land area is under agriculture, using around 90 per cent of the total water withdrawals in the country (FAO, 2015) [11]. Agriculture sector is the third-largest consumer of power in India; it accounted for 19% of the total power consumption in 2011 (D & B). Apart from the high use of resources by agriculture systems, agriculture also contributes to 19 per cent of the total greenhouse gas emissions from India, where by India's greenhouse emissions are the third largest in the world (Ministry of Environment, Forest and Climate Change, 2007). It is one of the sectors that not just contributes to causing climate change but also faces one of the worst impacts from the same due to the variability in weather conditions that can disrupt crop cycles. India needs to ensure availability of food for every citizen, now and for the future. The agriculture systems are responsible for achieving India's food security, ensuring livelihood security for farmers. Both of this will have to be achieved in the paradigm of depleting environment, shrinking natural resource base and climate change impacts on resources and agriculture. Some distinct concerns on Indian Agriculture Systems

- **Estimated shortage of food:** If current trends continue, India will not have enough food for all by 2030. India's domestic production is estimated to only meet 59 percent of the country's food demand by 2030 at the current growth rate of Total Factor Productivity (TFP) (Global Harvest Intiative, 2014) [15].
- **Increasing vulnerabilities due to climate change**: Food production in India is sensitive to climate change like variations in temperature and monsoon rainfall. Rise in temperature has a direct impact on the Rabi crop and every 1ºC rise will reduce annual wheat production by 6 million Tonnes when the total wheat production in India has on an average been 87 million tonnes per annum from 2008-2013, which makes a loss of 7 percent of the total production every year. Another study estimates a 4% fall in the yield of irrigated rice crop and a 6% fall in rainfed rice are foreseen by 2020 due to climate changes (Shetty, 2013) [41]. Climate change is also expected to reduce the regional water availability for food production due to rising temperatures, changing precipitation patterns and increasing frequency of extreme weather events (Ranuzzi & Shrivastava, 2012) [35]. Agriculture sector itself contributes 19 per cent of the total carbon emissions, being the third largest carbon emitting sector in India (Ministry of Environment Forest and Climate Change, 2010).
- **Shrinking natural resource base for agriculture**: Agriculture sector will witness a resource crunch with shrinking resource base as India already stands at an overshoot of 1.7 times its biocapacity1(Global Footprint Network, 2010). With 70 percent of the surface water polluted and 60 percent of groundwater sources expected to be in a critical state within the next decade (Indo German Environment Group, 2013), the impeding water crisis is one of the major health, environmental and

economic issues the country is likely to face. According to Integrated Waste Land Development Programme (IWPD) information platform at present, approximately 68.35 million hectare land is lying as wastelands in India out of which 50% lands can be made fertile again if treated properly. In addition a substantial acreage of individual lands is also left fallow.

Most of these lands belong to small and marginal farmers due to factors like non-availability of basic infrastructure, daily compulsion of earning income and negligible remuneration from agricultural activities.

- **Degrading natural resources:** Apart from the shrinking resource scenario, natural resources are also witnessing resource degradation due to various anthropogenic factors that affect the quality of resources available for practicing agriculture. India is losing 5,334 million tonnes of soil every year due to soil erosion because of indiscriminate and excess use of fertilisers, insecticides and pesticides over the years. About one millimetre of top soil is being lost each year due to soil erosion and the rate of loss is 16.4 tonnes per hectare (The Hindu, 2010) [21]. Introspection on results from the multiple long-term fertiliser trials in rice-wheat systems have revealed gradual deterioration of soil health and thus long-term productivity due to overuse and imbalance use of synthetic fertilisers (Roy, Chattopadhyay, & Tirado, 2009) [39].

FAO in 2010 developed a conceptual framework for an ecosystem approach to sustainable crop production intensification (FAO, 2010) [10]. The main objectives of developing a Conceptual Framework for sustainable crop production intensification are to: Increase understanding of the importance of biodiversity and ecosystems, and their sustainable management; identify options available for sustainably increased crop production; and provide guidance for decision makers at different levels (from land users to policy makers). The Conceptual Framework is intended to be flexible, to adapt to evolving situations, new scientific evidence and to incorporate valuable experiences from traditional knowledge. The circles suggest cross-cutting topics: the inner circle comprises farm-level factors; the mid-circle comprises the regional level (ecosystem boundaries or watershed-level factors); and the outer circle refers to national policy dimensions.

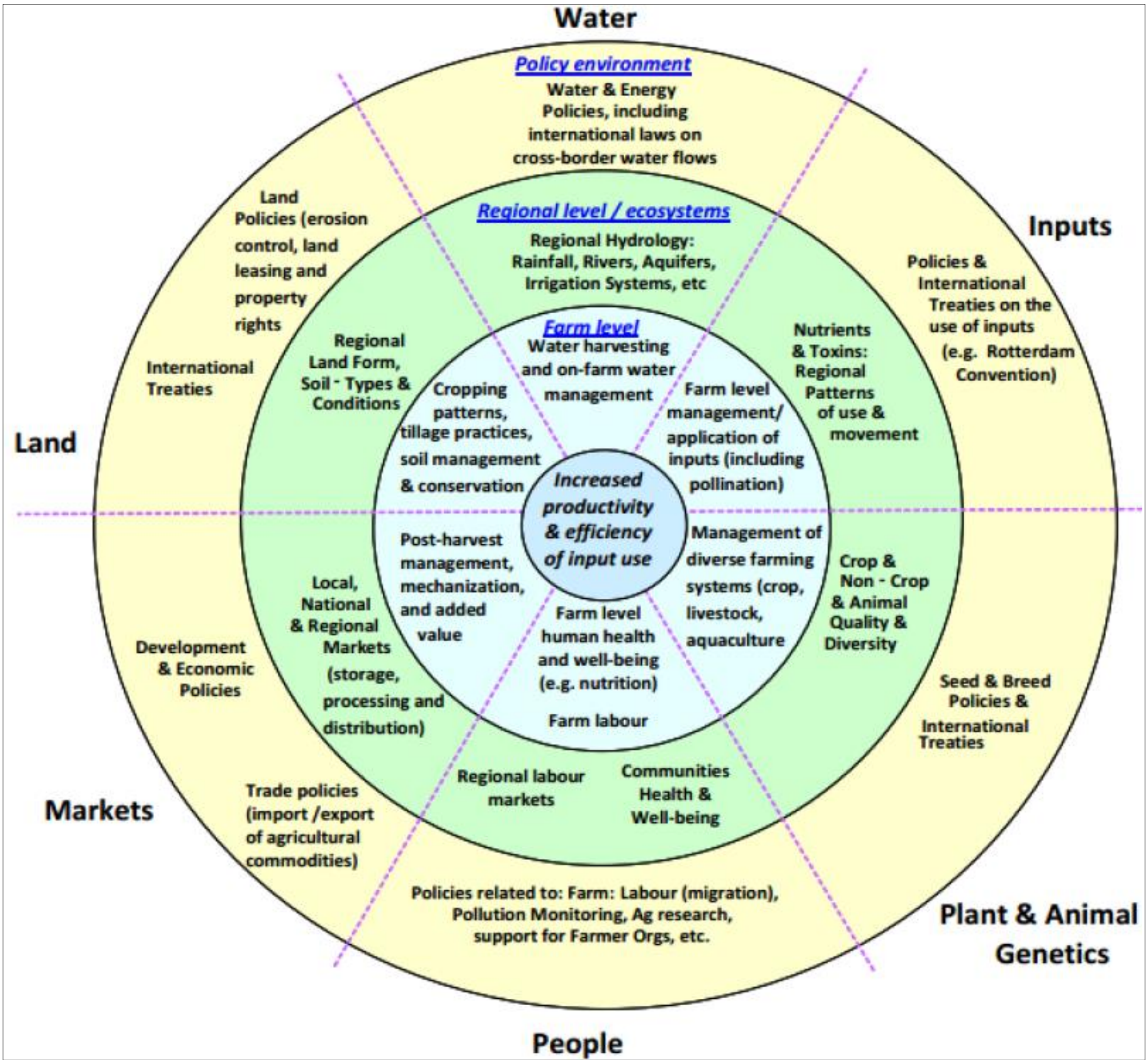

Fig 4: Sustainable Crop Production intensification overview (FAO, 2010) [10].

a. Food production security

Agriculture systems are responsible for ensuring adequate food production for the country's food requirements. The Agriculture Sustainability framework (Rao & Rogers, 2006) [36] on agriculture systems by measuring the agro-ecosystem stress points. The pressure indicators define stress on the system as characterized by trends in major multidimensional attributes of agricultural sustainability (productivity, stability, reliability, resilience and adaptability). In the light of the same, the features that highlight food production security are:

- **Productivity:** Productivity, as the capacity of the system to produce specific outputs is looked with overall production systems and total output from farm which includes food, fuel, fodder, manure and bio-inputs. Any positive change in productivity per unit resource shall be recorded as positive.
- **Resilience:** Resilience is the capability of the system to return to stable equilibrium after facing shocks or disturbances (e.g. drought, flood, markets), to reduce risk and vulnerability of the system. Any intervention that builds shock bearing mechanism in an agriculture system thus ensuring stable food production during disturbances will be taken as positive development under this component.
- **Adaptability:** Adaptability refers to the ability of the system to adapt its functioning to an entirely new set of conditions (e.g. climate change, World Trade Organization (WTO) regime). The interventions that allow the farmers and agriculture systems to adapt to the changing climate will be studied under this component.

This study does not take stability and reliability under the food production security indicators. The stability indicator measures the impact of agriculture practices on natural resource management and will therefore be covered under the component of environmental sustainability.

b. Sustainable livelihoods

In the Sustainable Rural Livelihood Framework (Rao & Rogers, 2006) [36], the sustainable livelihood strategies of individuals and households depend on access, use and development of five different types of assets – natural capital (land, water, biodiversity), physical capital (infrastructure, machinery), human capital (labour, skills), financial capital (savings, disposable assets), and social capital (rights, support systems). The components that define sustainable livelihoods are:

- **Natural Capital:** Any positive changes in land size, land use, fodder availability, water availability, and ground water shall be considered as positively affecting livelihoods.
- **Human Capital:** Increase in the knowledge and capacities to perform agriculture with higher benefits shall be accounted under this component as positive impact on livelihoods.
- **Financial Capital:** Access to finance for investment, increase in farm incomes shall be accounted here as positive impacts on livelihoods.
- **Physical Capital:** Availability and access to infrastructure, electricity, and agriculture equipment shall be accounted as positive under this parameter.
- **Social Capital:** Membership to community organizations, institution building shall be taken as positive indicators under this component.

c. Environmental sustainability

Stability, one of the five components of agro-ecosystem stress in the Agriculture Sustainability framework, is the ability of the system to reproduce processes needed to attain specified outputs (e.g. input use efficiency). Stability in this sense is derived from ecology and refers to preservation of the natural resources base. The state indicators determine the vulnerability of the agro-ecosystems and are characterized by environmental impacts indicators. The crop-ecosystem balance shall be assessed under this section. This includes any practice or input that impacts the health of environment- soil, air and water will be included:

Water resource

The study will assess change in the use of water per unit hectare. It will also account the change in the source of water amongst irrigation, ground water and rain-fed. This component will also take into account the water levels of ground water during extreme dry seasons.

Soil

Change in the use of fertilizers per hectare, pesticides per hectare shall be taken into account under this component. Any changes in the soil moisture witnessed as a result of a change in practice or intervention will also be taken in to account.

Air

Any changes in the amount of fossil fuel used for farm machines and the quantity of fertilizer used (since it uses fossil fuel for its production) shall be documented to study the impact on air from agriculture systems. The carbon emissions due to animal husbandry are beyond the scope of the study.

Enhancing agricultural production necessitates a well-designed cropping system suited to the land, the environment, and the people who derive their livelihood from it. Sustainable agricultural systems must be based on principles that restrict land degradation, conserve natural resources, and increase food and nutritional security for the smallholder farmers. Among the many sustainable cropping systems available to smallholder farmers limited to rain-fed practices, conservation agriculture (CA) can reverse soil degradation, improve crop production, and enhance the socio-economic condition of smallholder farmers. Reduced tillage and leaving crop residue in the field improves the soil while crop diversification, intercropping and rotation can provide food, income, and nutritional security. However, smallholder farmers achieve different economic efficiencies while employing the same CA techniques Debebe *et al*. (2015) [7]. A step towards greater food security and sustainability then is to maximize technical efficiency of an adopted CA developed via a transdisciplinary approach.

Biofertilizers and biopesticides a holistic approach for agricultural sustainability and food security

India has witnessed phenomenal economic growth with greater technology innovations, booming service sector, accelerated globalisation of the economy. However, facts indicate that India's development trajectory has ignored the role that natural resources play in India's development. With 70 percent of the surface water polluted and 60 percent of groundwater sources expected to be in a critical state within the next decade, the impeding water crisis is one of the major health, environmental and economic issue the country is likely to face. Food security is one of the key priorities of this country that has direct linkages with the use and quality of resources. Food security is dependent on agriculture which accounts for 70 percent of total global freshwater withdrawals and about 30 percent of total energy consumed globally.

Kannaiyan (2000) [21] also found that its very much essential to develop a strong workable and compatible package of nutrient management through organic resources for various crops based on scientific facts, local conditions and economic viability. Panchagavya (Cowpathy), Jeevamruth and Beejamruth are cheaper eco-friendly organic preparations made by cow products namely dung, urine, milk, curd and ghee. The Panchagavya is an efficient plant growth stimulant that enhances the biological efficiency of crops. It is used to activate soil and to protect the plants from diseases and also increase the nutritional quality of fruits and vegetables. It is used as a foliar spray, as soil application along with irrigation water, seed or seedling treatment etc. Three per cent Panchagavya is an ideal concentration for the foliar spray. Jeevamruth promotes immense biological activity in soil and makes the nutrients available to crop.

Anbukkarasi and Sadasakthi, (2011) [2] indicated that basal application of *Albizia lebbeck* as green leaf manure along with seed treatment and foliar spray of *Annona squamosa* leaf extract recorded the highest yield parameters *viz*., fruit length (21.55 cm), fruit girth (7.59 cm), number of seeds per fruits (59.20), fruit weight (18.33 g), yield (13.96 t ha^{-1}) with a benefit cost ratio of 3.78 and also quality parameters *viz*., lowest crude fibre (6.17 per cent), highest crude protein (14.27 per cent) and vitamin C (14.10 mg/100g) of Bhindi. Nandhakumar and Swaminathan, (2011) [44] indicated that there were significant differences in yield attributes of maize due to the incorporation of green leaf manures and foliar spraying of tree leaf extracts. All the yield parameters were found to be high in the plot that received *Albizia lebbek* as green leaf manure with foliar spraying of *Annona squamosa*. Anbukkarasi and Sadasakthi, (2013) [3] reported that among the treatment combinations, *Albizia lebbeck*+ *Annona squamosa* recorded the best performance for physiological parameters *viz*., dry matter production, crop growth rate and relative growth rate and highest uptake of N, P and K. The least incidence of pest and diseases also recorded in *Albizia lebbeck* with *Annona squamosa*. Swaminathan and Premalatha, (2014) [44] revealed that Soil incorporation of fresh leaves of tree species *Albizia lebbek* (vagai), *Senna siamea*, *Gliricidia sepium*, *Leucaena leucocephala*, *Delonix regia* (Gulmoher), at the rate of 10 tha^{-1}, was done 45 days prior to sowing of green gram and this served as basal nutrition to the crop followed by or foliar nutrition of leaf extracts at 5 % concentration of four tree species *viz*., Alangium *salvifolium*, *Annona squamosa*, *Aegle marmellos*, *Morinda tinctoria* during 30 and 45 days after sowing. It is observed that among the leaf incorporations, *Gliricidia* is found to be good and among the growth enhancers, *Aegle marmellos* is the best followed by *Morinda* tinctoria. However, application of leaves of Gliricidia sepium @ 10.0 tha^{-1} 45 days before sowing of green gram and, followed by that two sprayings of leaf extracts of *Aegle marmellos* @ 5% during 30 and 45 days after sowing recorded an average yield of 2.14 tha^{-1} and DMP of 7.63 tha^{-1}.

Ali *et al*. (2012) [1] reported that black gram, Shasyagavya @ 20 and 10% spray and *Kunapajala* @ 5 and 10% spray produced better yields whereas highest yield was recorded with *Shasyagavy*a 20% (0.11 kg m^{-1}). In mustard, the only yield indicator which significantly varied among the treatments was 1000 seed weight. The average 1,000 seed weight was maximum (2.56 g) with *Shasyagavya* 10% spray and minimum (1.5 g) in control. Notably, *Kunapajala* 3% spray exhibited better result for most of the characters as compared to other treatments in mustard. Asha, (2006) [4] showed that *Kunapajala* treated Langali (*Gloriosa superba* Linn) plants exhibited excellent result in terms of general growth of the plants and fruiting when compared to control group and chemical fertilizer group. Narayanan (2006) [30] revealed that improved modifications in the preparation of *Kunapajala* by mixing *Panchagavya* Show tremendous results when applied to vegetable.

Mishra (2007) [25] studied the growth of paddy using *Kunapajala* for every 10 days showed significant increase in growth parameters like plant height, leaf length, inflorescence length, number of grains per in florescence etc. Bhat Ramesh and Vasanthi, (2008) [5] reported that the application of *Kunapajala* in Brinjal shows large number of branches, higher yield, fruits with lesser seeds and lower susceptibility to diseases when compared with plants grown with artificial fertilizer. Deshmukh *et al*. (2012) [8] revealed that *kunapajala* treatment is superior to conventional farming and organic farming as it brings about physiological, biochemical and enzymatic enhancement in the leaves of tomato under organic farming conditions. Chadha *et al*. (2012) found that the application of vermiwash gave 60, 10, 26 and 27% higher yield in Knol Khol (211.67qha^{-1}), onion (177.81qha^{-1}), French-bean (16.3qha^{-1}seed yield), Pea (16.3qha^{-1}) and paddy (28.45qha^{-1}), respectively over control. Panchagavya, Matka Khad, Vermi-wash and Jeevamrti as foliar were also proved quite effective in enhancing the productivity of different crops and effective against various plant pathogens. Combined application of biofertilizers caused considerable increase in plant height and tillering and accordingly, the highest grain yield in wheat when the crop received combined bio-fertilizers (Singh *et al*., 2011) [42]. Bio-fertilizers in combination with inorganic fertilizers resulted in significantly higher yield in comparison to alone application of inorganic fertilizers in field pea (Jehangir *et al*., 2012) [18]. In rice under low land conditions, application of BGA + Azospirillum proved beneficial in improving LAI and all yields attributes (Mishra *et al*., 2013) [26]. Higher grain and straw yields with combined use of Rhizobium and PSB in *Pisum sativum* L 35 and increase in grain yield and nutrient uptake in gram by Rhizobium and PSM co-incolution (Dudeja *et al*., 1981) [9]. Seed bacterization with Rhizobium and organic amendments in acid soils significantly enhanced plant growth, nodulation and grain yield in green gram and black gram (Nagaranjan and Balachandar, 2001) [28]. Potash solubilising bacteria applied to soil @ 2.5 kg ha^{-1} after mixing it with 200-500 kg FYM resulted in increase in crop yield by 25% in paddy crop (Singh *et al*., 2011) [42].

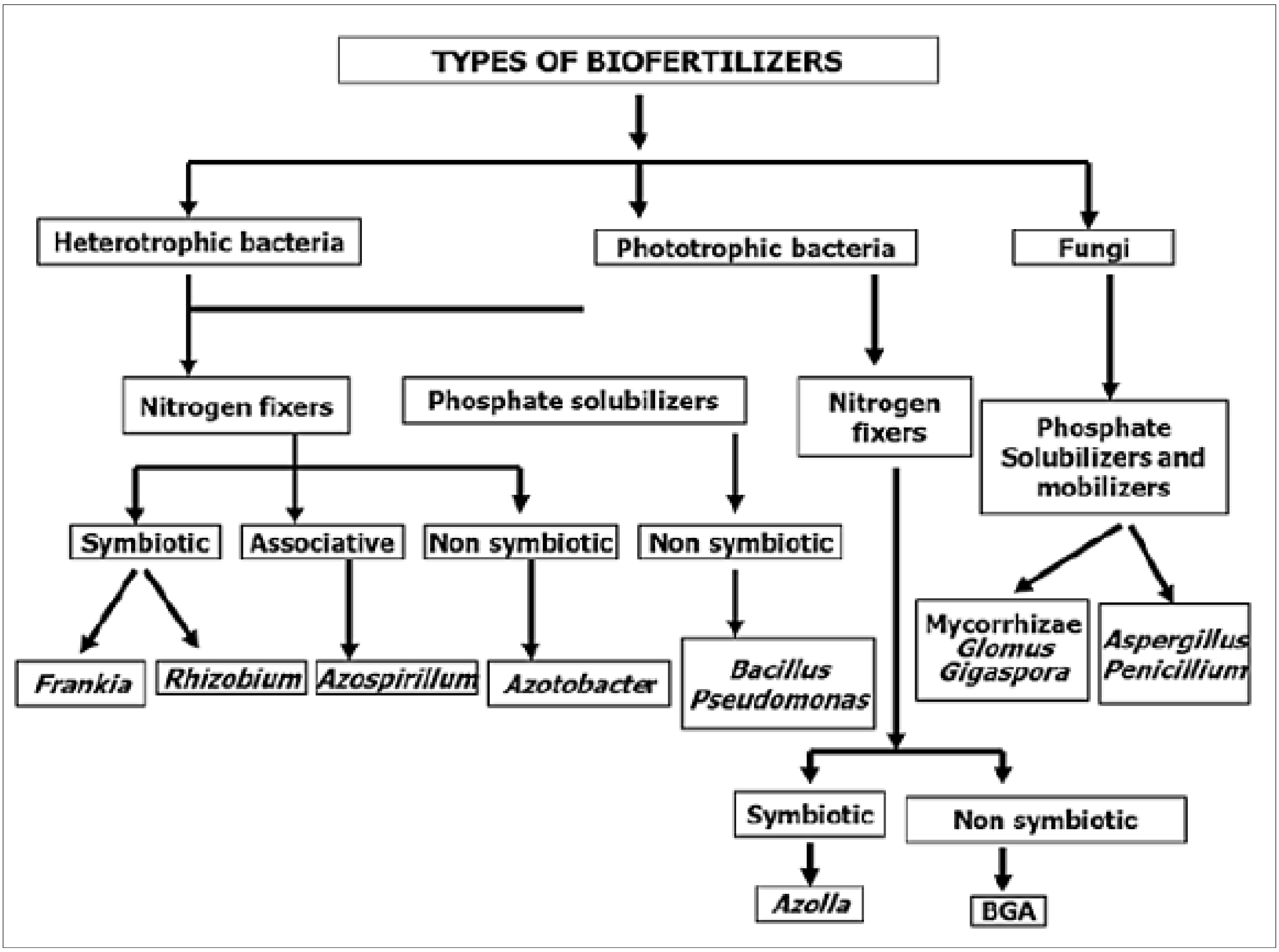

Fig 5(a): Types of biofertilizer and their functions (Motsara *et al*., 1995) [27].

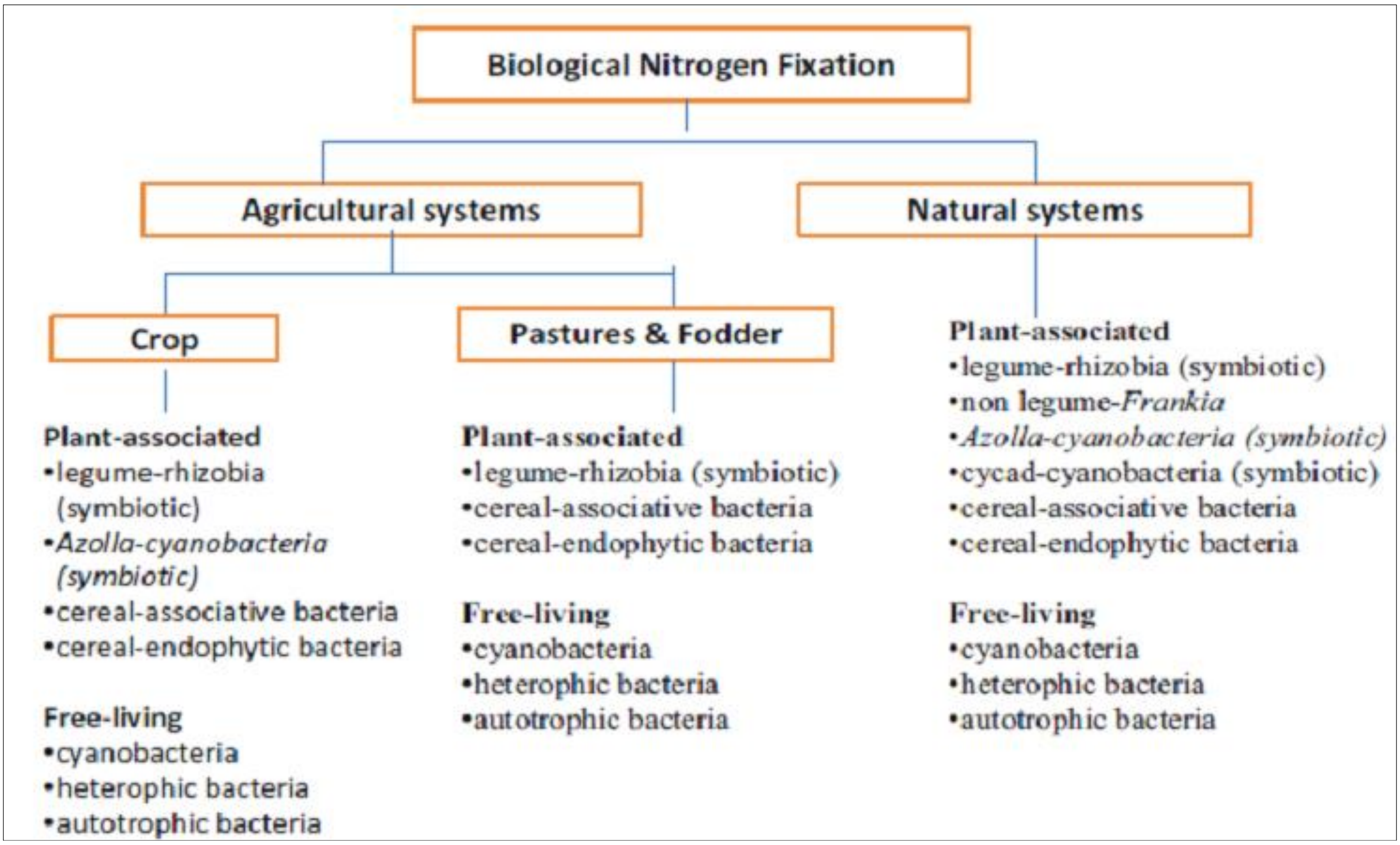

Fig 5(b): Biological nitrogen-fixing agents in agricultural and terrestrial natural systems (Herridge *et al*., 2008) [16].

Conclusion

Agricultural development is a particularly complex issue because it requires a long-term, integrated and broad perspective. It means that a very wide vision of the sector itself is needed, including dynamic links to overall economic development, natural resources, demographic and social issues, and the trends affecting these aspects in the long term. This report has addressed the issues of agricultural development from the perspective of FSN in all its dimensions (availability, access, utilization and stability). It aims at proposing pathways for sustainable agricultural development to confront the many challenges in order to enhance its contribution to food security and nutrition.

Biofertilizers are low-cost inputs with high benefits in agriculture. There is a need to popularize this low-cost technology with the farming community to reap higher dividends. The implementation of integrated nutrient management technologies by farmers is gloomy at field level. Incorporation of micronutrients is essential to increase pulse production in deficient soils of India. About 40% of the pulse-growing regions have low to the medium population of native Rhizobium. In these circumstances, productivity of pulse may be increased by 10–12% via seed inoculation with low-cost rhizobial biofertilizer. AMF inoculant is promising to improve the supply of phosphate and micronutrients like zinc for a variety of pulse crops, while phosphate solubilizers are the best option in rainfed areas of poor P availability.

CA principles appear to be universally applicable because the practice of CA is not a blanket recommendation or recipe for everywhere but has to be adapted to the site and farmer circumstances. CA produces more from less, can be adopted and practiced by smallholder poor farmers, builds on the farmer's own natural resource base, does not entirely depend on purchased derived inputs, and is relatively less costly even in the early stages of sustainable production intensification. CA being a new paradigm for most farmers globally, special emphasis must be placed on the need of a change in mind set amongst farmers especially in traditional farming communities in the North and the South and the importance of involving all stakeholders to apply a holistic approach in CA promotion that is just as much farmer driven as it is science driven and supported by public and private sectors and national agriculture development policies. Smallholder farmers no longer have the option of shifting cultivation as their not-so-distant ancestors did. Consequently, the continual cultivation of land requires approaches, such as CA, that maintain productivity, increase yield, and provide resilience to the farm communities. CA provides resilience to changing patterns of rainfall, builds and maintains the soil structure, and adds organic matter for better plant growth and moisture retention. By increasing yields and introducing additional crops, CA can increase food security for smallholder farmers. The farmers may consume the added production or sell the increased yield in the market providing income to purchase food.

In considering innovative pathways to SAD, there are many hurdles to overcome, not least the inertia of existing food systems and institutional frameworks that can favour the status quo. Alternatives and transitions may also be constrained by production and consumption path-dependency and technological lock-in. To change direction is costly, with uncertain results, and takes time. Moreover, the direction of change can be controversial, in part because it will impact the patterns of distribution of power, costs, benefits, and risks along the food chains. Different pathways also imply different requirements of knowledge and resource needs, and challenge the resilience of systems (Thompson and Millstone, 2011) [45]. This paper highlights operational priorities for action, taking into account the constraints and perspectives of different policy makers and stakeholders. It acknowledges that there could be two kinds of priority areas of intervention: the most critical which are often also the more difficult to implement, and those that could show quick progress. In some cases, the most pragmatic way to move forward from CA to SAD is to begin by actions that are easy to implement, backed not only by strong scientific evidence but also by sufficient political support and interest from stakeholders. Success in this first step could be catalytic in the sense that it will not only change the orientation of agricultural developments but also the perspectives of different stakeholders. This could help to build a political consensus allowing the implementation, in a second step, of more ambitious actions.

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