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Zero budget natural farming viable for small farmers to empower food and nutritional security and improve soil health: A review

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Abstract

Agriculture faces many challenges, making it more and more difficult to achieve its primary objective - feeding the world – each year. Population growth and changes in diet associated with rising incomes drive greater demand for food and other agricultural products, while global food systems are increasingly threatened by land degradation, climate change, and other stressors. Uncertainties exist about regional and local impacts of climate change, but the overall global pattern suggests that the stability of the food system will be at greater risk due to short-- term variability in food supply. Humankind has to nourish about 9.5 billion people by 2050 which requires maintaining the integrity of the soil and water resources with changing global climate system. Land degradation is a worldwide challenge, substantially affecting productivity in more than 80 countries and especially serious in developing countries. The impact of land degradation has already put at risk the livelihoods, economic well-being, and nutritional status of more than 1 billion people in developing countries (FAO, 2009).

Agriculture must change to meet the rising demand, to contribute more effectively to the reduction of poverty and malnutrition, and to become ecologically more sustainable. Poverty and hunger must be eradicated in our generation and should therefore be a prominent stand-- alone goal. The majority of the world's poor people live in rural areas, and agriculture growth has proven effective in lifting rural families out of poverty and hunger. Managing the linkages between agriculture, poverty and nutrition is critical as we look towards providing children with an opportunity to reach their full potential. Land degradation adversely affects the ecological integrity and productivity of about 2 billon ha, or 23 percent of landscapes under human use and up to 40 percent of the world's agricultural land are seriously degraded. India with 2.4% land area supports more than 17% of the world population. Achieving food security under the regime of climate change will require a holistic system approach, incorporating the principles of natural farming or conservation agriculture (CA), and judicious crop rotation.

Zero budget natural farming (ZBNF) an offer workable options to eradicate poverty and hunger while improving the environmental performance of agriculture, but requires transformative, simultaneous interventions along the whole food chain, from production to consumption. It also requires unprecedented, large-- scale behavior change by consumers as well as producers of food. Long- lasting solutions will require re-- thinking of rural development and smallholder agriculture towards structural transformations that include and benefit the poor. Improved farming systems and new technologies and business models can create decent jobs, allow the overcoming of resource constraints, enable greater market participation, and also lessen physical hardships in agriculture.

Keywords: Sustainable solutions, organic agriculture, nutrition security, evergreen revolution

Introduction

Agricultural production more than tripled between 1960 and 2015, owing in part to productivity-enhancing Green Revolution technologies and a significant expansion in the use of land, water and other natural resources for agricultural purposes. The same period witnessed a remarkable process of industrialization and globalization of food and agriculture. Food supply chains have lengthened dramatically as the physical distance from farm to plate has increased; the consumption of processed, packaged and prepared foods has increased in all but the most isolated rural communities.

Nevertheless, persistent and widespread hunger and malnutrition remain a huge challenge in many parts of the world. The current rate of progress will not be enough to eradicate hunger by 2030, and not even by 2050.

At the same time, the evolution of food systems has both responded to and driven changing dietary preferences and patterns of overconsumption, which is reflected in the staggering increases in the prevalence of overweight and obesity around the world.

Expanding food production and economic growth have often come at a heavy cost to the natural environment. Almost one half of the forests that once covered the Earth are now gone. Groundwater sources are being depleted rapidly. Biodiversity has been deeply eroded. Every year, the burning of fossil fuels emits into the atmosphere billion of tonnes of greenhouse gases, which are responsible for global warming and climate change.

All of these negative trends are accelerating in pace and intensity, and agriculture is an important part of the problem. Deforestation, mainly for farming, produces a significant share of global greenhouse gas emissions and causes the destruction of habitats, the loss of species and the erosion of biodiversity. The incidence of natural disasters has increased fivefold since the 1970s. Deforestation, the degradation of natural buffers protecting coastlines and the poor state of infrastructure have increased the likelihood that extreme weather events will escalate into full-fledged disasters for affected communities and the economy. The lengthening of food chains and changes in dietary patterns has further increased the resource-, energy-, and emission-intensity of the global food system.

These trends threaten the sustainability of food systems and undermine the world's capacity to meet its food needs. Although the full implications of climate change on agriculture, forestry and fisheries are difficult to predict, it is expected that the impacts will be of different levels and of a different nature in each region, ecological zone and production system. Even small changes in the climate, for example slight shifts in annual rainfall or seasonal precipitation patterns, can severely affect productivity.

All the nations facing problems of poverty, hunger and malnutrition will need to accelerate their agricultural growth for achieving sustainable development goals (SDGs), especially while aiming at no poverty, zero hunger and safe environment for all (Paroda, 2017) [22]. The Green Revolution not only led to food self-sufficiency but also helped to reduce the poverty and hunger. And yet, despite fivefold increase in food grains production, as against a fourfold increase in population, India still has around 250 million people who live in poverty and about 45 million children below five years of age who are malnourished.

Moreover, after 50 years of Green Revolution, India is also facing the second generation challenges like decline in the factor productivity growth, poor soil health, loss of soil organic carbon, ground and surface water pollution, water related stress, increased incidence of pests and diseases, increased cost of inputs, decline in farm profits and the adverse impact of climate change. On the demographic front, India adds annually almost one Australia (about 15-16 million) to its population. Thus, any progress gets nullified by an overall increase in population. Also, around 48% of the population is currently dependent on agriculture and allied fields and the agriculture sector contributes around 17% to national gross domestic product (GDP). Moreover, the public sector capital investment in agriculture and rural development has declined from almost 20% during Green Revolution period to currently less than 10%. As a result, most farmers are not benefitted especially since majority of them are smallholders and find agriculture not profitable any more.

Can we sustainably feed a world population of 11 billion?

Looking ahead, the core question is whether today's agriculture and food systems are capable of meeting the needs of a global population that is projected to reach more than 9 billion by mid-century and may peak at more than 11 billion by the end of the century. Can we achieve the required production increases, even as the pressures on already scarce land and water resources and the negative impacts of climate change intensify?

The consensus view is that current systems are likely capable of producing enough food, but to do so in an inclusive and sustainable manner will require major transformations. This raises further questions. Can agriculture meet unprecedented demand for food in ways that ensure that the use of the natural resource base is sustainable, while containing greenhouse gas emissions and mitigating the impacts of climate change? Can the world secure access to adequate food for all, especially in the low-income regions where population growth is the most rapid? Can agricultural sectors and rural economies be transformed in ways that provide more and better employment and income earning opportunities, especially for youth and women, and help stem mass migration to cities with limited labour-absorptive capacity?

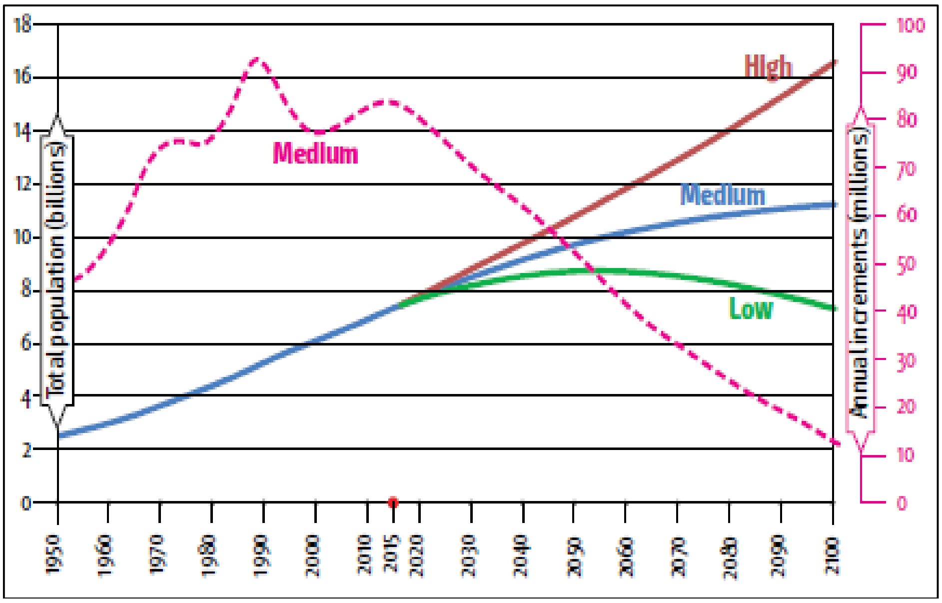
Can public policies address the so-called 'triple burden of malnutrition', by promoting food systems that give affordable access to food for all, eliminate micronutrient deficiencies and redress the overconsumption of food? Can the huge problem of food losses and waste, estimated at as much as one-third of the total food produced for human consumption, be tackled?

Can national and global regulatory structures protect producers and consumers against the increasing monopoly power of large, multinational, vertically integrated agro-industrial enterprises? Can the impacts of conflicts and natural disasters, both major disrupters of food security and the causes of vast migrations of people, be contained and prevented?

This raises further questions in another area: policy coherence. Can we overcome 'wickedness' in policy-making, where the lack of a coherent set of well-defined goals and processes means that the response to one aspect of a problem (e.g. incentives to raise productivity) risks exacerbating others (e.g. depletion of natural resources)? Can we engage all stakeholders, including the private sector, farmer and consumer organizations, and other civil society players, in better decision-making, recognizing that more inclusive governance is essential to improving dialogue about the hard policy choices that need to be made?

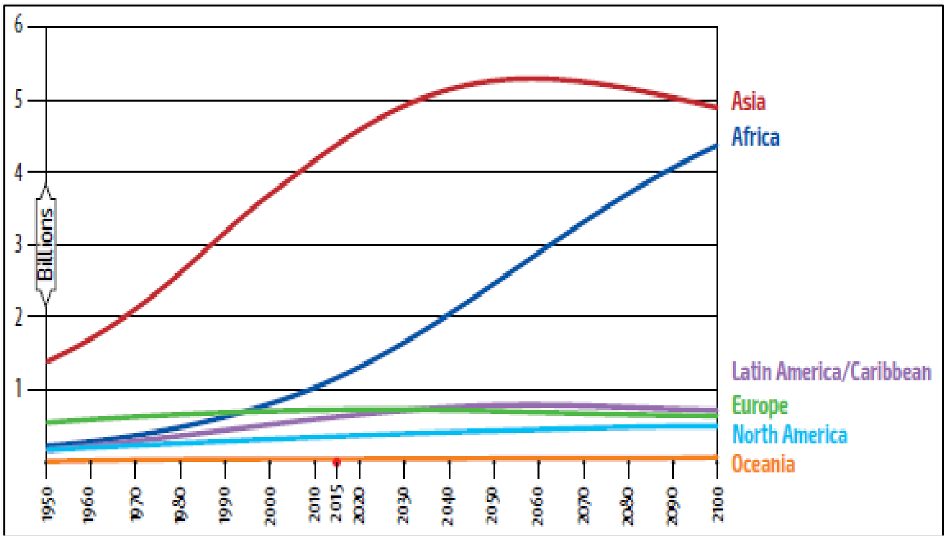
Global population growth is slowing, but Africa and Asia will still see a large population expansion

In its projections, FAO has always considered, as a key driver of changes in demand for food and agricultural products, not only population in absolute numbers but population dynamics, which include



Note: Annual increments are 5-year average

Fig 1(a): Global population growth to 2100, by variant



Note: Annual increments are 5-year average, ***Source:*** UN, 2015

Fig 1(b): Population growth to 2100, by region (medium variant)

diversity in regional trends, structure by age groups, and location For the world as a whole, annual population growth rates have been declining for nearly five decades. At their highest point in the late 1960s, global growth rates reached 2 percent per year, with total fertility rates (TFR) at levels of 4.5.[2] With TFRs declining to 2.5 in 2015; annual global population growth rates fell to 1.2 percent. Despite declining world population growth rates, absolute annual increments have continued to increase until very recently, when they started to decline noticeably. Currently, the absolute annual increments are slightly below 80 million people [Figure 1a].

The medium variant suggests a gradual decline in absolute increments to slightly over 55 million people by 2050, and a further decline to 15 million per year by the end of the century. Cumulatively, these increments translate into a world population of 9.73 billion by 2050 and 11.2 billion by 2100.

The global trends mask considerable differences across and within regions and between high-income and middle- and low-income countries. While the high-income countries would reach their maximum population size by 2040, low- and middle-income countries would see only slow declines in growth over the medium and even the longer term. There are also considerable differences in population growth rates within low-income countries. Asia, the most populous continent, would reach its population peak between 2050 and 2060 [Figure 1b].

East Asia is expected to see a continued and increasing deceleration of growth rates and a shrinking overall population after 2040. South Asia will continue to grow beyond 2070 and only reach its zenith sometime after that point. Growth is also expected to slow in Latin America, but more moderately, and the region will not reach its maximum population size before 2060. More rapid and more durable growth is projected for the Near East and North Africa region, where increases come to a halt only after 2080. The only region where the maximum population size will not be reached within this century is Africa. While the region's growth rate will continue to decelerate, its population is set to continue to expand beyond the end of the century and is expected to reach more than 2.2 billion by 2050 and more than 4 billion by 2100. The net effect across all regions will be a continuously growing global population, possibly surpassing 11.2 billion people by 2100.

Rapid urbanization is accelerating the dietary transition

For decades, the world's population was predominantly rural. Thirty-five years ago, more than 60 percent of all people lived in rural areas. Since then, the urban-rural balance has changed markedly, and today slightly more than half of the global population (54 percent) is urban. Thirty-five years from now, in 2050, more than two-thirds of all people may be living in urban areas (UN, 2015).[4] Changes in agriculture, notably technical progress and the adoption of labour-saving technologies, have helped underpin increasing urbanization. At the same time, agriculture, food and nutrition have been, and are likely to continue be, affected by the changes brought about by urbanization.

In absolute terms, global urbanization to 2050 could lead to a net addition of 2.4 billion people to towns and cities, which is more than the total global population increment of 2.2 billion people. This means that rural populations may see a net reduction of nearly 200 million people [Figure 2a]. The net reduction of rural populations reflects much more than simply an outflow from rural to urban areas – it is driven by a variety of factors, notably higher mortality rates in rural areas and shorter life expectancies. These factors more than offset the lower urban fertility rates. While urbanization was a high-income country phenomenon up to the 1970s, rapid growth in low-income countries has since become the defining feature of global urbanization dynamics. The sheer size of urban populations in low-income countries now determines the global dynamics [Figure 2b].

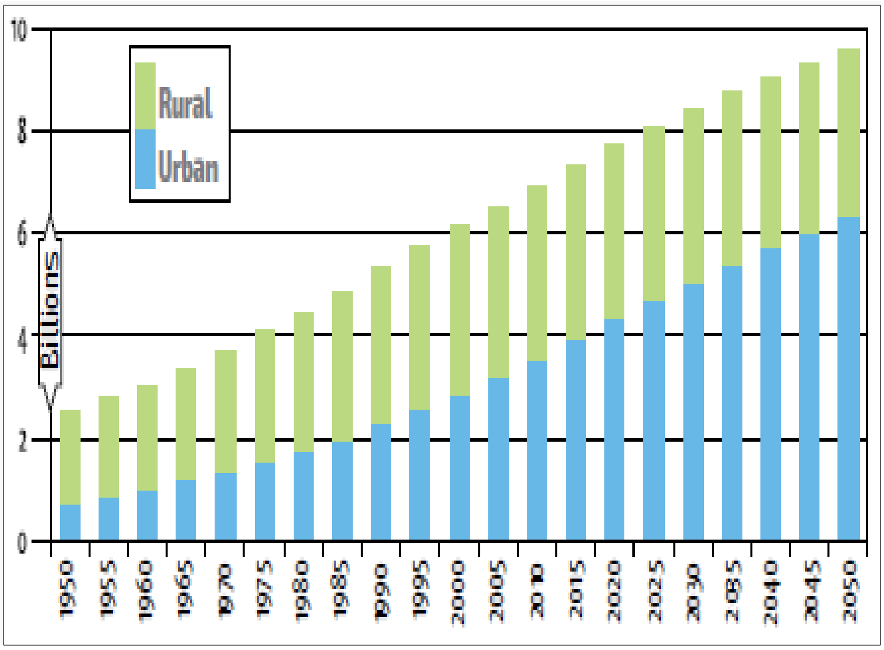
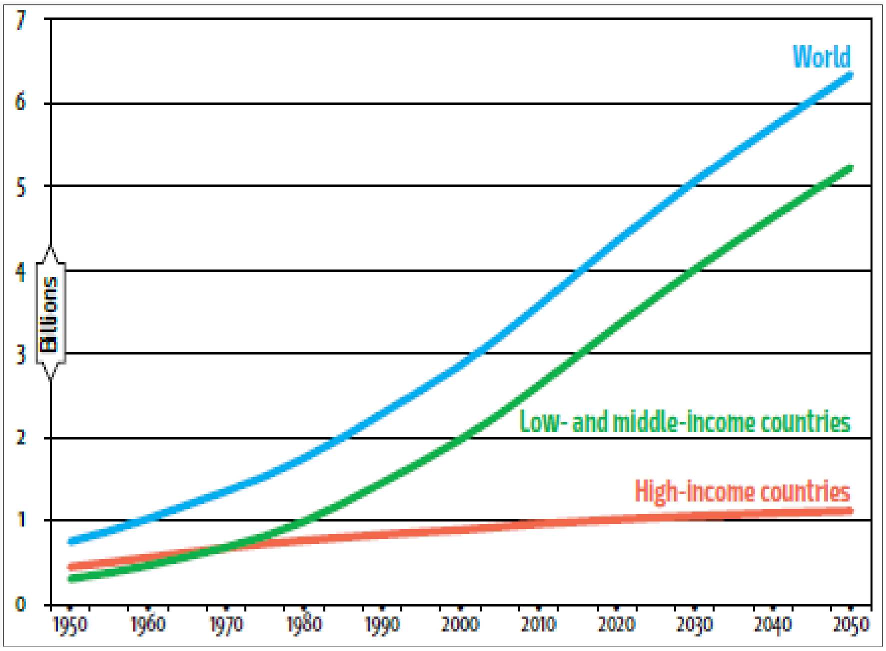


Fig 2 (a): Growth in global urban and rural populations to 2050

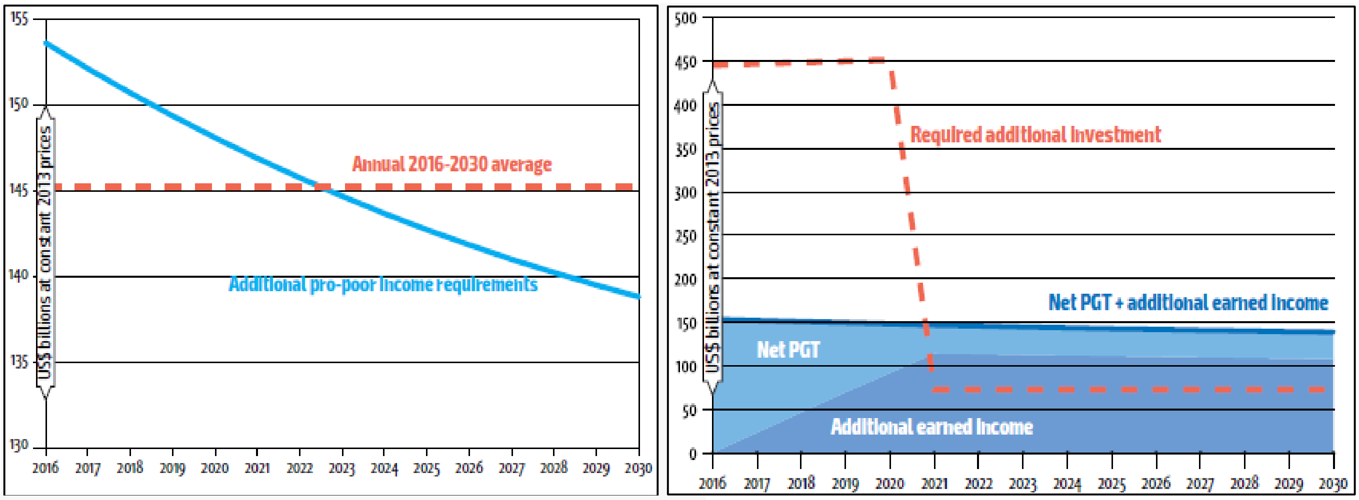


Source: UN, 2015

Fig 2 (b): Urbanization trends, by region

Business-as-usual' investment patterns would leave hundreds of million people undernourished to 2030

Under a business-as-usual scenario, the prevalence of hunger would fall, but more than 650 million people, or 8 percent of the global population, would still be undernourished in 2030 (FAO, IFAD and WFP, 2015). The report estimated that, globally, additional investments required to end hunger by 2030 would amount to US$265 billion a year. These investments would be needed for both social protection programmes (US$67 billion), which would improve access to food for vulnerable populations, and for investment in pro-poor productive activities (US$198 billion) that provide low-income earners with structural opportunities to earn, save, invest and improve their livelihoods.



Note: PGT is Poverty Gap Transfer. Source: FAO, IFAD and WFP, 2015

Fig 3: Additional income and investment to eradicate hunger by 2030

While social protection, identified by the Poverty Gap Transfer (PGT), is expected to provide a great proportion of the required additional income until 2020–21 (light blue area in Figure 3, bottom), additional earned income (dark blue area) may progressively outpace income from social protection, thanks to significant investment in the early years of the period (red dashed line, Figure 2.10, bottom). These investments are expected to provide people currently living in extreme poverty with an average of around

US$145 billion of additional annual income, which they need to escape from hunger and extreme poverty by 2030 (red dashed line, top).

The expansion of agricultural land continues to be the main driver of deforestation

The global expansion of agricultural land has stabilized over the last 20 years at around 4.9 billion hectares (ha), while forest losses have amounted to less than 100 million ha [Figure 4a]. Globally, net forest conversion has been decreasing over the last 15 years [Figure 4b], and annual losses have been reduced by 50 percent since 1990 (FAO, 2015). Projections indicate a need for less than 100 million ha of additional for agricultural use in 2050 (Alexandratos and Bruinsma, 2012) [2].

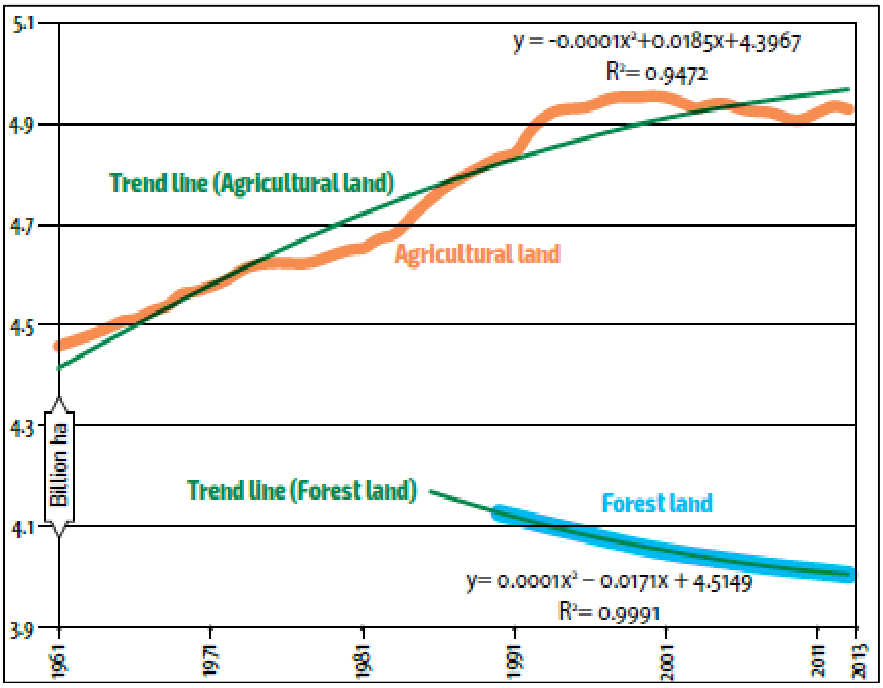
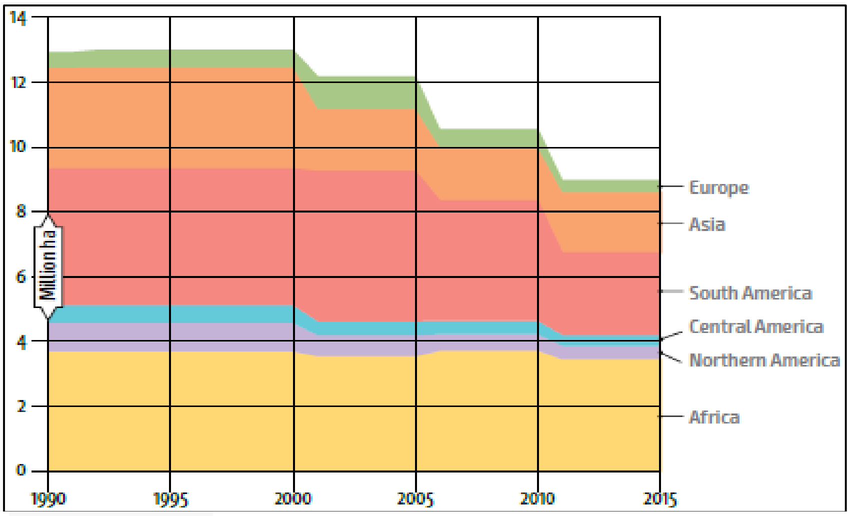


Fig 4 (a): Agricultural and forest land uses 1961-2013



***Source*:** FAO, 2016b

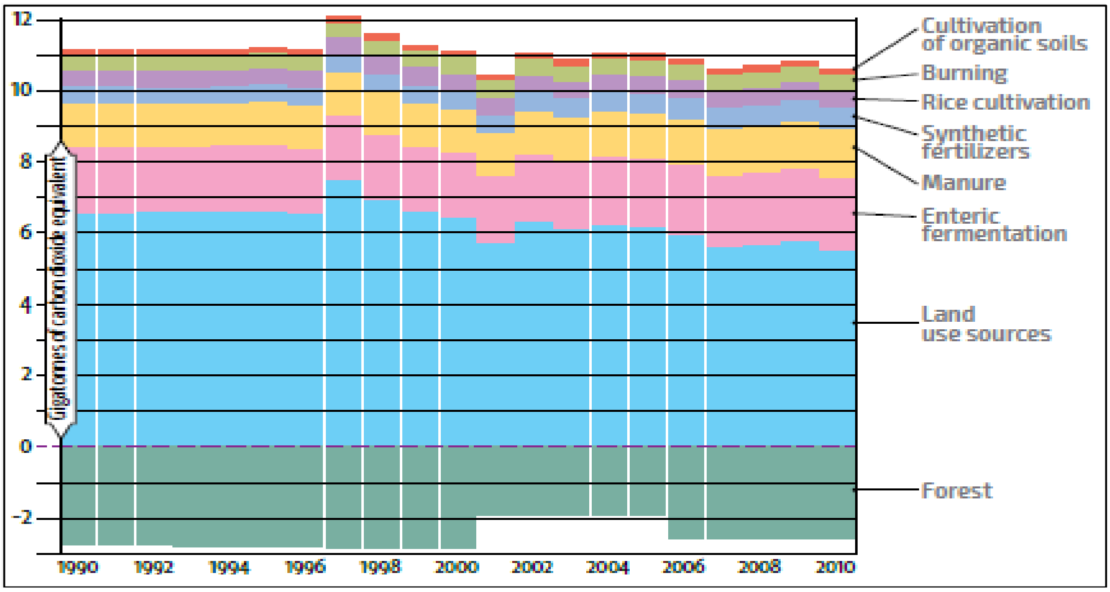
Fig 4 (b): Net forests conversion, by region, 1990-2015

Food and agriculture sectors contribute substantially to greenhouse gas emissions, but mitigation options exist

Over the past 50 years, greenhouse gas (GHG) emissions resulting from 'Agriculture, Forestry and Other Land Use' (AFOLU) have nearly doubled, and projections suggest a further increase by 2050 (Tubiello *et al.*, 2014) [35]. In 2010, emissions from the AFOLU sector were an estimated 10.6 gigatonnes (Gt) of carbon dioxide equivalent, and were mainly caused by land use, livestock production, and soil and nutrient management [Figure 5a]. The sector produces an estimated 21 percent of total global GHG emissions (FAO, 2016e, Figure 5b). However, forests also mitigate climate change by removing GHG from the atmosphere through biomass growth. The average contribution of forests to carbon sequestration was around 2 Gt a year since the turn of the century. This implies that the annual net emissions of AFOLU were slightly above 8 Gt [Figures 5a and 5b].

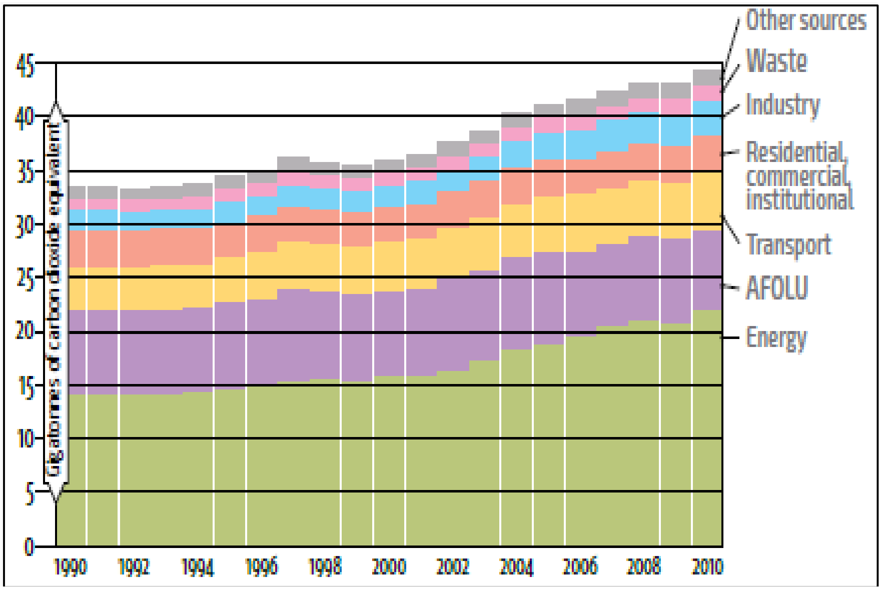
Agriculture contributes the largest share of global methane and nitrous oxide emissions. Most of its methane emissions are produced by enteric fermentation during the digestive processes of ruminant animals, and by rice cultivation. The nitrous oxide emissions originate mainly from the application of nitrogen-based fertilizers and animal manure management. The removal of GHG by forests has fallen from 2.8 Gt annually in the 1990s to an estimated 1.8 Gt in 2014 (FAO, 2016e). The decline is believed to be linked to increasing variability in climate and atmospheric composition. A 2016 study of biomass dynamics in the Amazon rainforest over three decades found that the region is losing its ability to sequester carbon dioxide owing to an increasing rate of biomass mortality (Brienen *et al.*, 2016).

Emissions produced by the use of energy in primary agriculture (e.g. fuel for tractors) are not included in the IPCC's AFOLU classification. If they are taken into account, emissions from the sector rise by a further 0.9 Gt (FAO, 2016c). If GHG emissions resulting from energy use in processing, trade and consumption of food (approximately 3.4 Gt) are also considered, the total amount of net GHG emissions from the food and agriculture sector would amount to 12.3 Gt, or around 26 percent of total GHG emissions (FAO, 2011).



Note: The classification of emissions is according to FAO, 2016c. 'Manure' includes 'manure left on pasture','manure management' and 'manure applied to soils'; 'Burning' includes 'burning – crop residues', 'burning –savanna' and 'crop residues'. Source: FAO, 2016c

Fig 5 (a): Annual greenhouse gas emissions from agriculture, forestry and other land use (AFOLU)

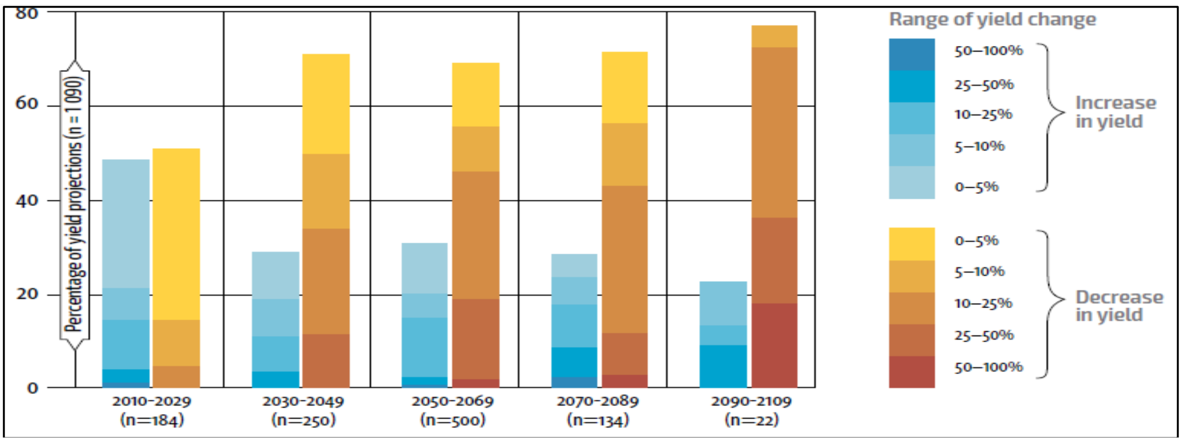


Note: 'Other sources' includes international bunkers. Source: FAO, 2016b.

Fig 5 (b): Annual greenhouse gas emissions from all sectors

Climate change will affect every aspect of food production

In its latest assessment, the IPCC has stated with high confidence that in low-latitude countries crop production will be 'consistently and negatively affected by climate change'. In northern latitudes, the impacts on production are more uncertain; there may be positive or negative consequences (Porter *et al.*, 2014) [24]. Increasing variability of precipitation and increases in the frequency of droughts and floods are likely to reduce yields in general. Although higher temperatures can improve crop growth, studies have documented that crop yields decline significantly when daytime temperatures exceed a certain crop-specific level (FAO, 2016e). The IPCC assessment report has stated with medium confidence that climate change will increase the inter annual variability of crop yields in many regions. The use of climate models in conjunction with crop models is contributing valuable insights into the possible impacts of climate change on yields. For the main cereals, projected yields, due to climate change under the different representative concentration pathways show significant regional increases and decreases but mostly downward shifts globally (FAO, 2016e). A meta-analysis of 1 090 studies on yields (primarily wheat, maize, rice and soybeans) under different climate change conditions indicates that climate change may significantly reduce yields in the long run [Figure 6].



Source: Porter *et al.*, 2014.

Fig 6: Projected changes in crop yields owing to climate change.

Are low- and middle-income countries trends continue, the target of eradicating hunger by 2030 will not be reached

The State of Food Insecurity in the World 2015 estimated that in 2014–16, some 775 million people in the low- and middle-income countries were unable to acquire sufficient food to meet their daily minimum dietary energy requirements over a period of one year (Table 1). This means that 13.2 percent of these countries' population did not consume the necessary average food energy supply of 2 620 calories per capita per day (FAO, IFAD and WFP, 2015b). Progress made towards the 1996 World Food Summit targets fell far short of the original ambition. Between 1990–92 and 2005, the number of under nourished fell by less than 70 million. The significant achievements made in East Asia (mainly China) were offset by little or no progress in sub-Saharan Africa and South Asia, where there are still high concentrations of undernourished people.

Table 1: Number of undernourished, 1990/92-2030

	1990-92 %	1990-92 millions	2000-02 %	2000-02 millions	2005-07 %	2005-07 millions	2014-16 %	2014-16 millions	2030 %	2030 millions
High-income countries	< 5.0	32	< 5.0	36	2.2	29	1.6	23	1.1	16
Low- and middle-income countries	29.7	978	24.5	894	17.6	920	13.2	775	9.3	637
East Asia	28.2	432	20.3	339	15.9	311	11.1	233	7.8	175
Latin America	22.1	66	18.3	60	8.4	47	6.1	37	4.0	27
Near East	14.5	20	24.8	33	8.3	36	6.5	33	4.7	29
South Asia	25.1	284	19.0	258	20.5	311	14.9	257	9.3	188
Sub-Saharan Africa	45.9	173	40.4	201	29.0	212	23.3	213	17.4	216
World	18.6	1011	14.9	930	14.4	949	11.0	797	7.9	653

Note: The regional aggregation follows FAO, IFAD and WFP, 2015a.

Sources: FAO Global Perspectives Studies, based on FAO, IFAD and WFP, 2015a, b.

Between 2005 and 2015, greater progress was made. Nearly twice as many people escaped chronic under nutrition during the last decade compared to 1990–2005. However, even if the recent rate of progress continues, this would still be insufficient to achieve the World Food Summit targets. When extrapolated into the future, and assuming the same faster pace of progress attained over the past 10 years, the target of eradicating hunger by 2030, foreseen in Sustainable Development Goal 2, would not be met. Progress in relative terms, i.e. reductions in the proportion of undernourished in the total population, has been more impressive.

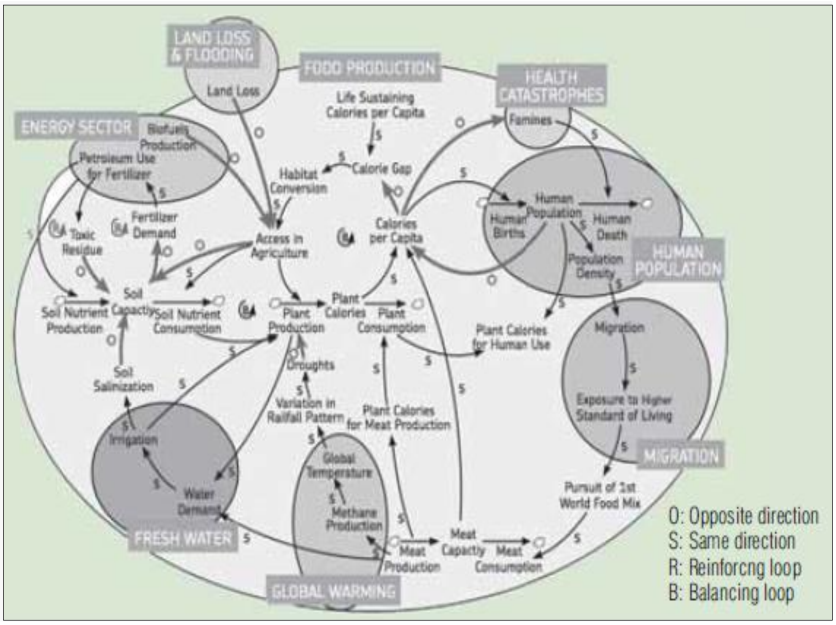
The prevalence of undernourishment fell by almost half between 1990 and 2016 in low- and middle-income countries (Table 1). This is close tothe Millennium Development Goal hunger target, which was to halve the proportion of undernourished. Some regions, such as Latin America, East and Southeast Asia, the Caucasus and Central Asia, and North and West Africa, have made particularly fast progress. While progress was also made in South Asia, Oceania, the Caribbean, and Southern and Eastern Africa, the pace was too slow to reach the MDG target. While overall progress in reducing the prevalence of hunger was driven by some very populous countries, it was not limited to these countries. A total of 72 low-income countries, out of 129 – or more than half of the countries monitored – have reached the MDG hunger target. Most of them enjoyed stable political conditions and economic growth, and often implemented social protection policies targeted at vulnerable population groups.

The most recent FAO projections of trends in undernourishment, provided in the report *Achieving zero hunger* (FAO, IFAD and WFP, 2015a), estimate the number of undernourished in 2030, under a 'business-as-usual' scenario, at 637 million people in low- and middle-income countries. This figure exceeds by 95 million people, or 17.5 percent, previous projections to 2030 reported for a mostly overlapping set of 'developing countries' in AT2050 (Alexandratos and Bruinsma, 2012) [2]. The number of undernourished projected in *achieving zero hunger* definitely falls short of the SDG target of eradicating hunger by 2030. That is why FAO, IFAD and WFP call for a twin-track approach, which merges investment in social protection to immediately raise the food consumption levels of the extremely poor, with pro-poor investment in productive activities to sustainably increase the income-earning opportunities of poor people. Social protection directly contributes to the reduction of poverty, hunger and malnutrition by promoting income

Zero Budget Natural Farming (ZBNF): it is, basically, a natural farming technique that uses biological pesticides instead of chemical-based fertilizers. Farmers use earthworms, cow dung, urine, plants, human excreta and such biological fertilizers for crop protection.

Saurabh Tripathi *et al.* (2018) [28] revealed that zero budget natural farming is resource efficient as it minimises the use of financial and natural resources while increasing crop yield. By restoring the quality of soil and water-related ecosystems, it decouples agricultural productivity and growth from ecosystem degradation and biodiversity loss. This decoupling of growth and resource-use provides a sustainable livelihood to farmers and allied value chain actors. Zero budget natural farming eliminates chemical fertilisers and pesticides, and would help reduce ocean acidification and marine pollution from land-based activities. It might help to reduce the leaching of nitrogen and phosphorous from the soil into groundwater or surface water, and eventually into rivers and oceans. Mulching techniques used by ZBNF farmers improve the water retention capacity of the soil, reduce crop irrigation requirements and control the concentration of groundwater contaminants.

In India Subhash Palekar reported that four aspects that are integral to ZBNF (1) *beejamrutham*, or microbial coating of seeds using cow dung and urine based formulations; (2) *jeevamrutham*, or the application of a concoction made with cow dung, cow urine, jaggery, pulse flour, water and soil to multiply soil microbes; (3) mulching, or applying a layer of organic material to the soil surface in order to prevent water evaporation, and to contribute to soil humus formation; and (4) *waaphasa*, or soil aeration through a favorable microclimate in the soil [Figure 7b]. For insect and pest management, ZBNF encourages the use of various *kashayams* (decoctions) made with cow dung, cow urine, lilac and green chillies.



Source: Herren (2012)

Fig 7 (a): Systemic embedding of climate friendly agriculture

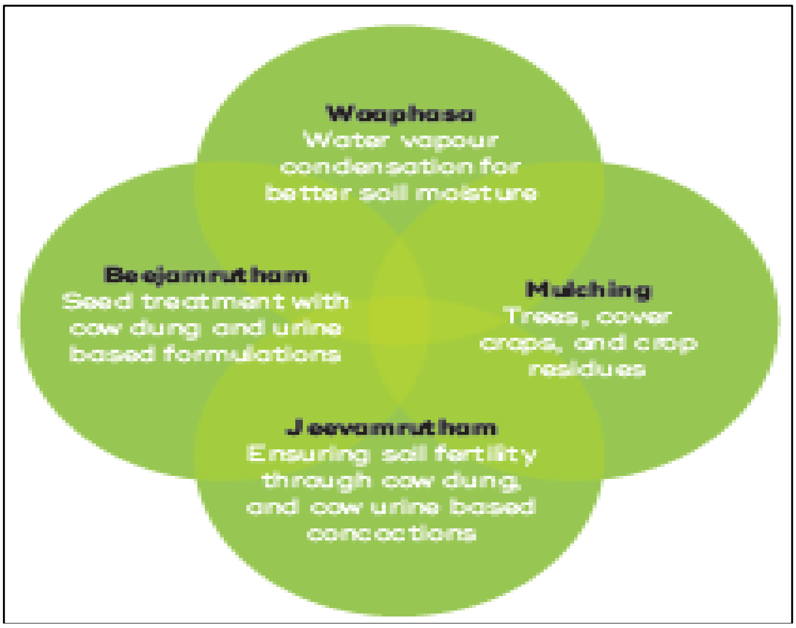


Fig 7 (b): The four-wheels of zero budget natural farming

The cow dung and urine used in the preparation of natural inputs are only from indigenous cows. These practices have been shown to have a positive effect on the quality of the soil, improving its fertility and water retention capacity. This is likely to reduce reliance on resources such as water and electricity for irrigation. Substituting chemical fertilizers and pesticides with natural inputs might reduce input costs and farmers' exposure to credit risks; the increase in net income will improve the cash flow of poor and vulnerable farmers, and may enhance their ability to deal with economic shocks; and the reduced resource-dependence and improved soil quality might then help farmers adapt better to extreme climate events.

Historically, Maharshi Vasishtha served the divine "Kamdhenu" Cow and Maharshi Dhanvantari offered to mankind a wonder medicine "Panchgavya" (a combination of cow urine, milk, dung, *ghee* and curd). In Sanskrit, all these five products are individually called "Gavya" and collectively termed as "Panchgavya". Panchgavya had reverence in the scripts of Vedas (divine scripts of Indian wisdom) and Vrkshyurveda (Vrksha means plants and Ayurveda means health system). Indian cow breeds are unique and distinct species, both in their appearance and characteristics. Cow is the backbone of Indian culture and rural economy, and sustains our life; represent cattle wealth and bio-diversity. It is known as "*Kamdhenu*" and "*Gaumata*" because of its nourishing nature like mother, the giver of all providing riches to humanity and is a store of medicines The Ayurveda, the ancient Indian system of medicine, has detail mentions of importance of cow's milk, curd, *ghee*, urine in the treatment of various human aliments. Every product has distinct qualities and uses in health, agriculture and other fields (Chauhan, 2005; Joshi, 2002; Achliya *et al.*, 2004; Saxena *et al.*, 2004) [5, 19, 1, 29]. Panchgavya has many beneficial implications in agriculture, zero budget natural farming as good quality natural manure and bio-pesticides, as alternate energy resources and high medicinal values. Bio-fertilizer and pest repellants obtained from cow urine and dung restores micro-nutrients and fertility of the soil and provides food free from health hazards of chemical fertilizers and pesticides. No other fertilizer in the world is as cheap and harmless as dung fertilizer. Dung and urine also provide valuable alternate source of energy in the form of biogas, fuel and electricity.

Cow urine as such and/or after addition of neem leaves is a wonderful bio-pesticides which do not accumulate in the food chain and as such do not have the harmful effects like chemical pesticides. Cow dung is excellent farmyard manure and if processed into vermi-compost, very small amount is sufficient for a large field. Though, the end user claims are many but scientific validation of those claims is required. The people frustrated from the heavy medication of allopathy are using cowpathy drugs and being benefited by the Panchgavya products. However, scientific validation of Panchgavya products is required for its worldwide acceptance and popularity in terms of agricultural, energy resource, nutritious and medicinal applications so as to exploit the optimal power of Panchgavya for the service of mankind.

One can do farming of 30 Acres using single Indian Deshi/Local Cow. Cow generally gives 9-11 kg of cow dung everyday and 1 gm of cow dung has 300 -500 Crores of Bacteria. For Jivamruta preparation requires 10 kg cow dung for 1 acre. The capabilities of these bacteria have to convert Dia Tri format atoms single format single atom and the smell of dung attracts the natural earthworm which is currently missing in the farms. Earthworm makes the land porous. This will eventually increase the water table of land.

Naresh *et al.* (2018) [20] *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. Vennila and Jayanthi, (2008) [37] revealed that application of 100 per cent recommended dose of fertilizer along with panchagavya spray (2%) significantly increased the number of fruits per plant, fruit weight g $fruit^{-1}$ and fruit yield q ha^{-1} of okra. Nileemas and Sreenivasa, (2011) [21] stated that application of liquid organic manure promotes biological activity in soil and enhance nutrients availability to tomato crop. Ali *et al.* (2012) [3] reported that black gram, *Shasyagavya* @ 20 and 10% spray and *Kunapajala* @ 5 and 10% spray produced better yields whereas highest yield was recorded with *Shasyagavya* 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. Gad *et al.*, 2012) noticed that foliar application of humic acid @ 2 g l^{-1} increased N% and protein% of seeds and recorded higher plant height, plant dry weight, pod diameter, fresh seeds weight pod^{-1},number of fresh seeds pod^{-1}, green pod yield, seeds weight dry pod^{-1}, dry seed yield, N,P and protein percent of pea seeds. Panwar *et al.* (2013) indicated that, application of Farmyard manure 5 t ha^{-1} + Vermicompost 2.5 t ha^{-1} + Jeevamrut 2 times (30 and 45 DAS) to kharif sweet corn recorded significantly higher values for sweet corn cob and green fodder yield. Microbial count of bacteria, fungi and virus was significantly increased with the application of Farmyard manure 5 t ha^{-1} + Vermicompost 2.5 t ha^{-1} + Jeevamrut 2 times (30 and 45 DAS) which was found at par with Farmyard manure 5 t ha^{-1} + Vermicompost 2.5 t ha^{-1} as compared with rest of the treatments. Jannoura *et al.* (2014) [18] revealed that organic fertilizer application improved nodule dry weight, photosynthetic rates, N_2 fixation, and N accumulation as well as N concentration in several crops.

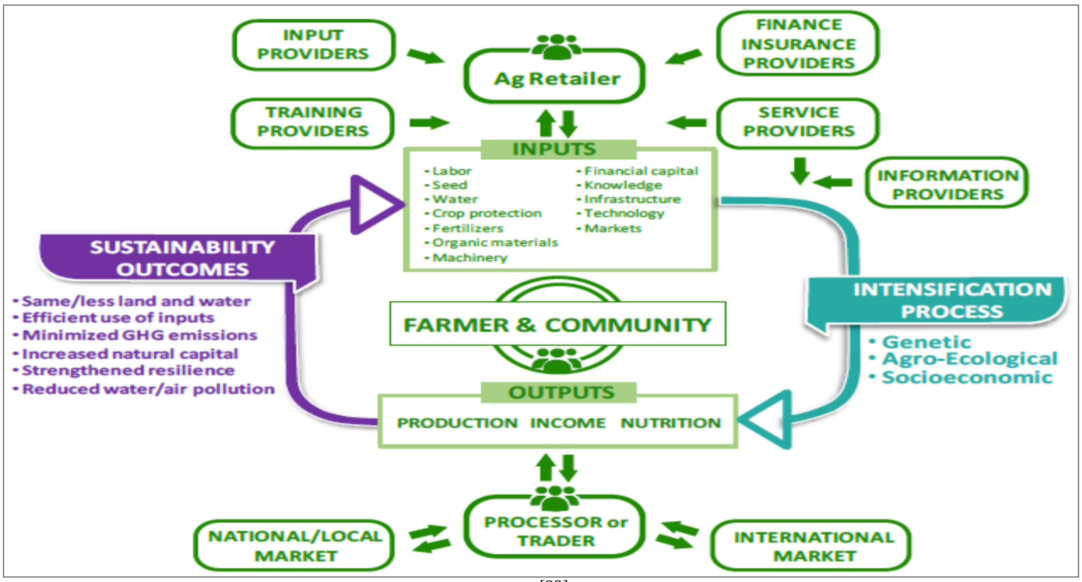
Crop residue management is key component of natural farming as well as CA and an important strategy for C sequestration. In India, over 620.4 million tons (Mt) of agricultural residues are produced every year (Jain *et al.*, 2014). In IGP, over 297.5 Mt of agricultural residues are produced every year, which is 47.9 % of the total CRs generated in India. However, 61.6 Mt of residue burnt every year in IGP, which is about 62.5 % of the total CRs burnt in India. Globally, principal residue management practices involve residue removal, residue incorporation and residue burning. Agricultural residues burning may emit significant quantity of air pollutants like CO_2, N_2O, and CH_4, which is responsible for global climate change and causes nutrient loss as well as soil degradation. One ton of wheat residue contains 4-5 kg N, 0.7-0.9 kg P, and 9-11 kg K (Singh and Sidhu, 2014). Yadvinder Singh *et al.*, (2010a) estimated 6 kg N ha^{-1} (15% of initial) in the sandy loam and 12 kg N ha^{-1} (27% of initial) in the silt loam from buried residue by maximum tillering stage. The amount of N released from the buried residue on the sandy loam increased to 12 kg ha^{-1} by the booting stage and to 26-28 kg ha^{-1} by maturity.

The highest positive balance of soil nitrogen was associated with application of neem leaf manure followed by neem leaf manure + Panchagavya spraying. Reduced losses of N from neem leaf manuring due to presence of nitrification inhibitors in neem leaf manure.Nitrification inhibiting alkaloids released from neem leaf manuring checks the faster rate of N mineralization (Srinivasulu Reddy, 1988). Sole application of organic manures recorded higher positive balance of soil phosphorus than they coupled with Panchagavya spraying. Application of organic manures resulted in increased production of organic acids during the decomposition which will reduce the fixation of native and applied phosphorus.

The buildup of phosphorus with organic manures in system based nutrient management has been reported by Singh *et al.* (2005) [30]. Hundal *et al.* (1992) [16] also elucidated the solubility action of the organic acids to enable higher nutrient uptake.

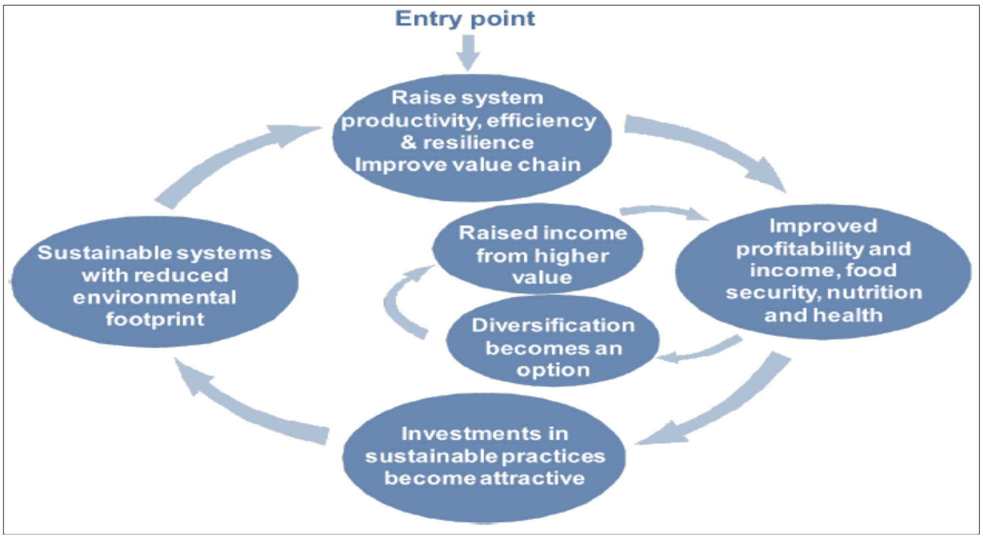
Ramesh and Rao (2009) [25] also reported that soil health could be sustained with organic nutrition due to diversification of soil biota. Rao *et al.* (2013) [25] observed that the dynamics of various soil fertility parameters *viz*., soil organic carbon, available nitrogen, available phosphorus and available potassium, all of them were found built up to a considerable extent with the use of organic manures to maize and sunflower, while the application of fertilizer to maize and sunflower could just maintain the soil fertility status with neither considerable replenishment nor deterioration. As regards the balance sheet of soil available N, P and K, the highest positive balance of soil available nitrogen was found associated with neem leaf manure, and that of phosphorus was associated with poultry manure while that of potassium was with vermicompost.

The Montpellier Panel (2013) [33] found that high priority must be given to helping farmers worldwide adapt to climate change and weather extremes by building more resilient agricultural systems. That requires making farming more precise by implementing agro-- ecological, as well as socioeconomic intensification measures, and having the necessary support systems in place for maximum impact [Figure 8a].



Source: Modified from The Montpellier Panel, (2013) [33].

Fig 8 a: Sustainable Agricultural Intensification and its enabling environment



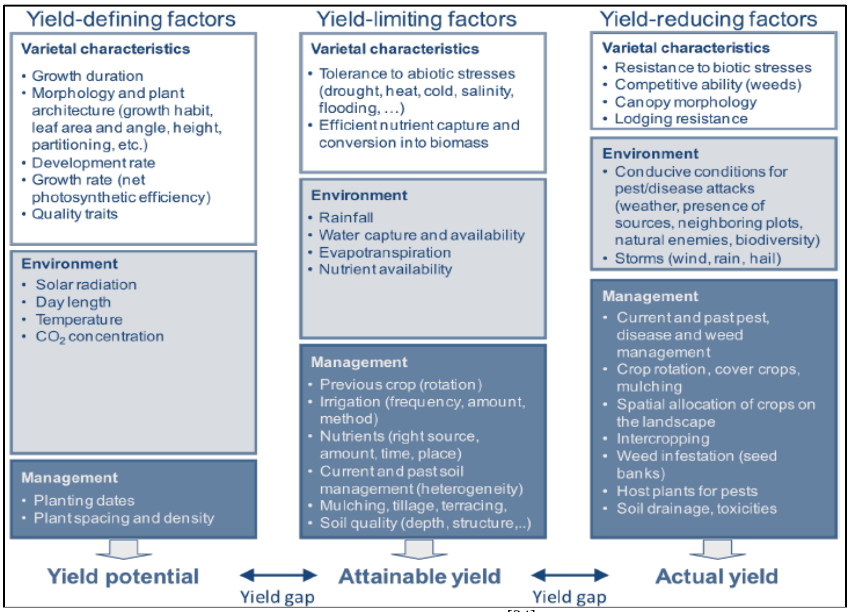
Source: Modified from IRRI (2006).

Fig 8 b: Enhancing system productivity and value is the entry point for enabling farmers to enter a virtuous circle of sustainable agricultural production and livelihood.

In practice, workable options -- actionable "solutions" -- must focus on raising the diversity, productivity, efficiency, resilience, value and therefore also the overall profitability of farming. This is the entry point for moving from the vicious circles trapping rural people in poverty or creating environmental problems towards virtuous circles of agriculture for sustainable development [Figure 8b]. Tittonell and Giller, (2013) [34] revealed that the right ZBNF strategy in a country, a precise understanding of yield, efficiency and/or product quality and value gaps, i.e., how large they are, where they occur, and what their biophysical and socioeconomic causes are, is needed at sub- national and local levels. Progress has recently been made in establishing better methodologies for yield gap analysis, mapping the yield gaps of major crops at global and regional scales, and understanding their different contexts. Although this is encouraging, a lot more remains to be done to obtain a deep understanding of yield and efficiency gaps in the world's major agricultural systems, at a scale that enables people to use this knowledge for concrete action in farmers' fields [Figure 9a].

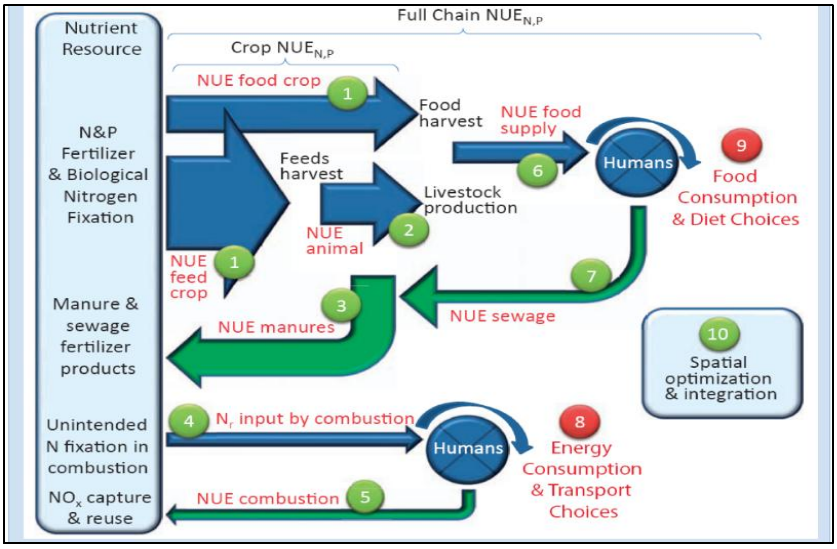
Ten key actions for improving nutrient use efficiency in food systems

Improving the full-chain Nutrient Use Efficiency (NUE) of nitrogen and phosphorus, defined as the ratio of nutrients in final products to new nutrient inputs, is a central element in meeting the challenge to produce more food and energy with less pollution and better use of available nutrient resources. Nutrient flow is a cycle from resources through stages of use (blue arrows) and recycling (green arrows). The system is driven by the 'motors' of human consumption (red), which are thus also a key part of the solutions needed for achieving future nutrient targets. The poorest need to be allowed to increase their food and other nutrient consumption, while the richest must realize that it is not in their own interest to over consume. There are significant differences in the cycles of nitrogen, phosphorus or other nutrients among and within countries that need to be taken into account in determining specific targets and interventions. Hence, the targets for nutrient use and NUE will vary among countries and so will the pathways for achieving them by addressing any of the specific components of the full-- chain NUE relative to their current state. Possible actions include (numbers in the graph): 1 Improve NUE in crop production; 2 Improve NUE in animal production; 3 Increase the fertilizer equivalence value of animal manure; 4 Low-- emission combustion and energy-- efficient systems; 5 Develop NO_X capture and utilization technology; 6 Improve efficiency in the fertilizer and food supply and reduce food waste; 7 Recycle N and P from waste water systems; 8 Energy and transport saving; 9 Lower personal consumption of animal protein; and 10 Spatial and temporal optimization of nutrient flows. Of the 10 solutions proposed, the first three are directly related to agricultural systems management. Specific targets and indicators can be defined for each of these steps [Figure 9b].



Source: Modified from Tittonell and Giller, (2013) [34].

Fig 9a: Yield- defining, yield- limiting and yield-- reducing factors determine the exploitable yield gaps in crop production.



Source: Sutton, M.A. *et al.* (2012).

Fig 9b: Our nutrient world: the challenge to produce more food and energy with less pollution

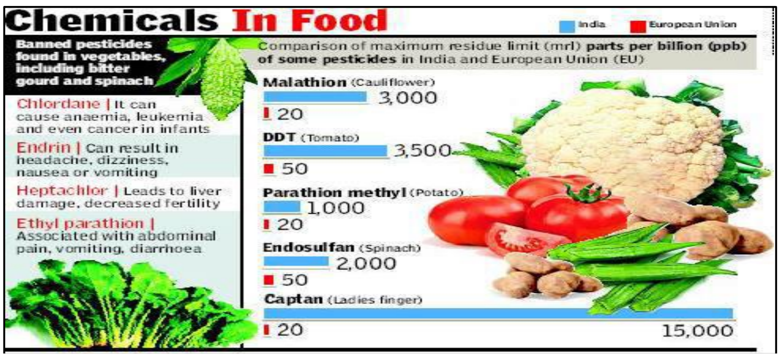


Fig 10a: Death threatening Pesticides all over India and European Union

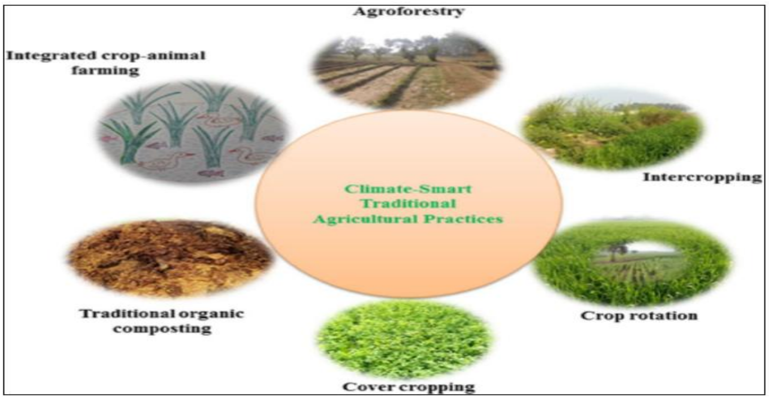


Fig. 10b: Climate smart traditional agricultural practices

Who is guilty for excess Pesticides in food?

Most of our farmers are unaware of the adverse effects of pesticides and honestly, I wouldn't really blame them for ignoring the long-term effects to the soil and falling prey to the lure of using pesticides and increasing their produce. Because in the end, they need to make ends meet too. Those who sell pesticides to farmers do not train them about the usage levels, precautions, etc. and as a result the farmers tend to use them indiscriminately. If at all anyone is to blame, I think it is us. We urban dwellers are so cut off from agriculture that we fail to realize how much the farmers' problems are going to affect us.

Remedy?

1. Use natural fertilizers to make soil healthy initially. Understand and use inter crop ecosystem to benefit from it. Use natural replacements for pesticides. Use techniques that Nature uses to improve and maintain soil quality.
2. Waapasa

Waaphasa is that microclimate in the soil, by which the soil organisms and roots can live freely with availability of sufficient air and essential moisture in the soil. In one sentence, shortly, the Waaphasa means the mixture of 50 % air and 50 % water vapors in the cavities between two soil particles. Why water vapor? Why not water? Because, any root takes the molecules of water vapor. 92 % microorganisms and 88 to 95 % root hairs are working in the upper most 10 cm surface soil. So, the air must be circulating in this surface layer and vapor molecule must be available in this 10cm surface layer. When this will happen? When, we give water outside the canopy of the plant. When you give water outside the canopy of the plant i.e. outside the shadow of the plant at 12 O' clock, then only Waaphasa will be maintained. The roots that take water are situated at the outer canopy.

Bio-energy based on pyrolysis and gasification of biomass can be a decentralized source of energy. Bio-fuels also offer scope wherever ecological and economic conditions are favorable. Biomass is an under-utilized resource. ''Bio-parks'' can be promoted in every block to convert the available biomass into a range of products, including energy and manure. Conservation farming and green agriculture are the pathways to an 'Evergreen Revolution', defined as increasing productivity in perpetuity without associated ecological harm.

Table 2: Steps in the evergreen revolution, defined as increasing productivity in perpetuity without associated ecological harm

Component	Description
Organic agriculture	Cultivation without any use of chemical inputs like mineral fertilizers and chemical pesticides
Green agriculture	Cultivation with the help of integrated pest management, integrated nutrient supply and integrated natural resource management systems
Eco-agriculture	Based on conservation of soil, water and biodiversity and the application of traditional knowledge and ecological prudence
Effective microorganism agriculture	System of farming using effective microorganisms
White agriculture	System of agriculture based on substantial use of microorganisms, particularly fungi
One-straw revolution	System of natural farming without ploughing, chemical fertilizers, chemical pesticides and herbicides

Conclusion

The unique opportunity to eradicate poverty and hunger in our generation and make agriculture and food systems more sustainable should not be missed. The primary objective of agriculture -- which cannot be compromised -- is to produce enough food to sustainably feed 9 or 10 billion people by 2050. This largely needs to be accomplished by crop and animal productivity increases, reducing food losses and waste, and changing diets, always keeping in mind that the Earth's natural resource base is finite.

In addition to the already common pressures of the past, our generation is facing new challenges: How to make sure that we do not run out of water? How to preserve or improve soils? How to adapt to climatic extremes? Is the best future for many smallholder farmers to get out of farming? How do we create better jobs and higher incomes for them in rural or urban areas? How do we ensure healthier diets and lifestyles in all countries? We live in an ever-- changing world in terms of population, resource demands and constraints, climate, and even political volatility.

Meeting future food demand will require shifts in behavior as well as shifts towards more sophisticated technologies, information and knowledge management systems for farming systems and whole value chains, but also policy-- making, and market and incentive systems for investment in ecosystem services.

We need to be realistic about the future of smallholder farming in developing countries. For many small farming households exiting the agricultural sector may be the best strategy to overcome current poverty traps caused by resource constraints that also restrict the adoption of better technologies.

The 2015 to 2030 period must become a period of serious transition towards food systems that operate based on SAI principles. It is possible to effectively end extreme poverty and hunger during this period, but it will probably take longer to completely halt and reverse all of the negative environmental and health impacts of contemporary food systems. However, if political will, governance and human behavior can change as rapidly as science and technology emerge, policy coherence for development, sustainable agriculture and food systems can become the new global standard, not the exception. Prosperous, Healthy and resilient rural communities will be needed to produce the world's future food in a sustainable manner. Concerted, coordinated action is needed, with increased, sustained investment in agriculture and rural development.

We need to make farming more precise and more attractive to systematically improve sustainability performance using new technology. We need new implementation models that can unlock the real potential of the public and private sectors in addressing complex problems, including monitoring, learning, and prudently adapting.

Markets alone are not enough; the private sector will also have to change its business models, and good governance will be essential, including more restraint in exploiting critical resources such as land, water, and forests. Aspirations of *maximum consumption* should be replaced by patterns of *optimized consumption*. The Available technical solutions are well advanced, but we also need to overcome systemic political, economic and social barriers to change, which are substantial. Strong multi - sectoral cooperation will be needed to address the development challenges facing humanity and the planet.

Farmers are encouraged to make use of agricultural waste instead of discarding or burning it. Crop residue, which can be reused for mulching, is useful for improving the nutritional content of the soil. As the crops are now cultivated without chemicals, farmers also feel safe in using crop residue as feedstock for cattle. This ultimately creates a cyclical system dependent on cattle - where the soil receives inputs from cattle waste, the crop receives inputs from soil, and the crop waste ultimately becomes feedstock for cattle. Wide-scale adoption of ZBNF would help reduce the release of harmful chemicals to the air, water and soil. It will minimise the adverse impacts on farmer and consumer health, and on biodiversity.

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