AGRIALLIS
Science for Agriculture and Allied Sector: A Monthly e Newsletter
Volume 3 – Issue 3
Online ISSN: 2582-368X
www.agriallis.com

SUSTAINABLE AND CLIMATE SMART AGRICULTURE: CHALLENGES AND OPPORTUNITIES IN INDIAN PERSPECTIVE

Article Id: AL2021153

Amrit Lal Meena[1*], Minakshi Karwal[2] and Raghavendra KJ[1]

[1]ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut-250110, India
[2]KIET group of Institutions, Ghaziabad, Delhi-NCR, India-201206, India

Email: amrit.iari@gmail.com

Supplying sufficient nutritive food for ever growing population has always been remained the most imperious challenge for the developing nations. During the twentieth century the developing nations tried to fulfil this challenge with increased agricultural production using external inputs i.e. synthetic fertilizers and other agrochemicals. The green revolution technology substantially increased the agricultural production with the help of modern agricultural practices at the cost of natural resources. Thus, a considerable decline in natural resources like degradation of soil fertility and environmental quality was observed. These adverse effects led to go with the approach of traditional agriculture with minimize use of external inputs. This approach has been defined as sustainable agriculture in recent time. The sustainable agriculture is the admixture of modern agricultural practices along with traditionally adapted healthy practices. Therefore, sustainable agricultureis not only resource conservative but resilient to current climate change scenario.

Being a sole food provider to the animal kingdom of the planet, agriculture employs a key role in economic development of agrarian economy like India. Agriculture based industries are the largest industry across the globe as it covers~ 40% of total available land. When it comes to the average per capita energy requirement ~78% of total per capita energy requirement is fulfilled by crop-based products, while ~20% energy is contributed by other products i.e. meat, milk and eggs (Singh *et al*., 2019). Thus, meeting out the food demand of ever growing human and animal population from decreasing land resource under agriculture is the major challenge in present scenario which can be only attained by increasing the agricultural production. Besides the non-agricultural use of agricultural land resources, changes in global climate is also a major concern for sustainable agricultural production. As per the reports of International Panel on Climate Change (INECC, 2010) enormous increase

Volume 3 – Issue 3
Online ISSN: 2582-368X
www.agriallis.com

in greenhouse gases emission (carbon dioxide, methane, nitrus oxide and chlorofluoro carbons) from both agriculture and non-agricultural sectors have led to increase in global temperature by 0.6 to 0.8 ºC and changes in rainfall patterns around the world. These adverse changes in global climate has directly or indirectly affected the sustainability of agricultural production across the globe. In India, agriculture and its allied sectors not only contribute to ~ 17% of total gross domestic product (GDP) but it also provides ~2/3 employment of total employment in India (Directorate of Economics and Statistics, 2019). The livelihood of rural population of India which is about 58% of total population directly depends on agriculture. Therefore, potential growth of Indian Agricultural sector is directly associated withpoverty alleviation and employment generation in developing economies like India. The dimension of Indian Agriculture can be illustrated from figure 1.

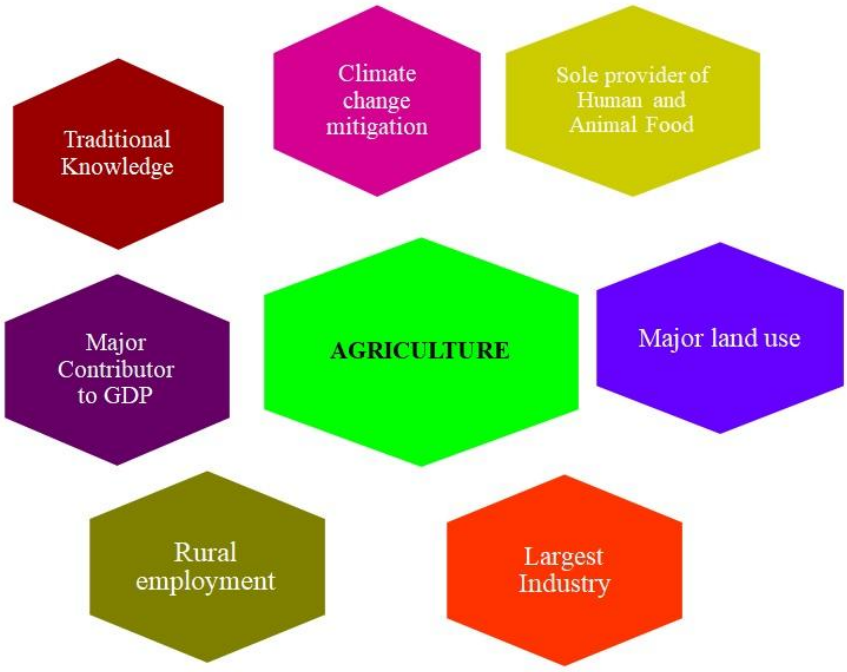


Fig. 1. Role of Agriculture in present scenario (Source: Singh et al., 2019)

Further, the agriculture industry is facing various challenges from different non-agricultural sectors and changing climate, therefore, the agricultural industry has adopted several measures to cope up with these challenges. The challenges to agricultural sector can be depicted from figure 2.

Volume 3 – Issue 3
Online ISSN: 2582-368X
www.agriallis.com

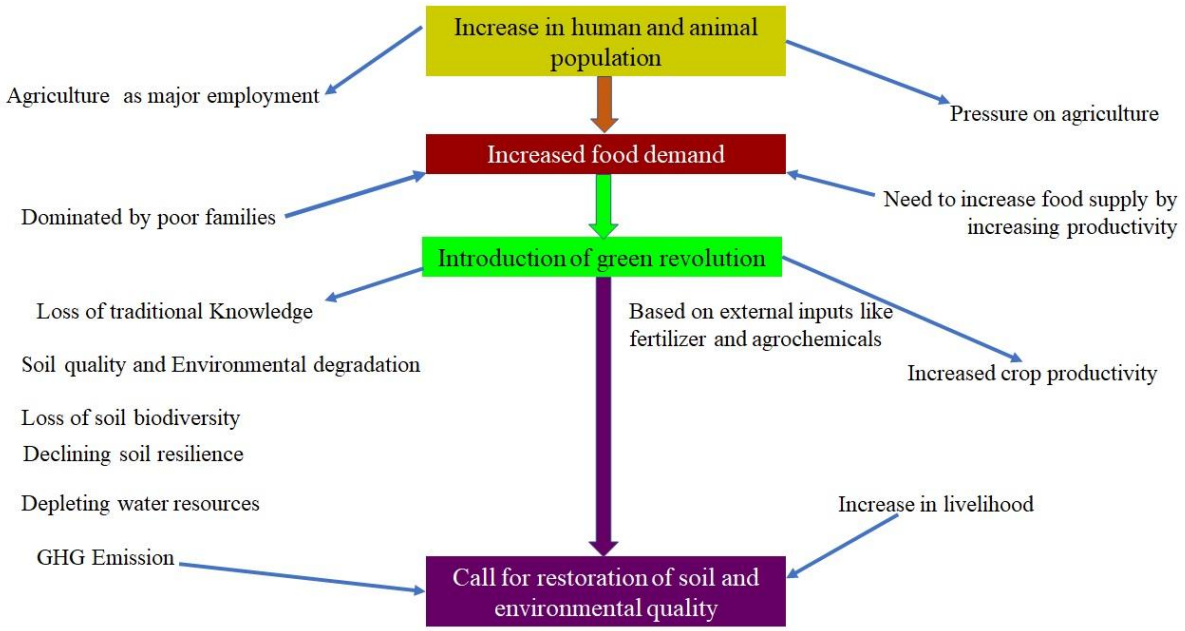


Fig. 2. Challenges and opportunities in agriculture sector (Source: Singh et al., 2019)

With the current decadal growth rate of 18%, the Indian population will be 1.5 billion by 2050 which has created enormous pressure on natural resources in India as India has only 2.2% of global geographical area. Only 46% area out of the total 32.8 Mha area is under cultivation in India. The green revolution was introduced in Indian agriculture in the later half of 20th century with the three basic principles i.e. meeting out the food demand of people, with limited natural resources and increase in crop production with the help of external inputs (Singh et al., 2017). This green revolution increased the agricultural production in India as much as 4 to 5 folds in comparison to 1950-51 and helped India to become self-sufficient in food production. Though, green revolution substantially increased the agricultural production but the adverse impacts of green revolution technologies in the later 20th century has led towards the critical scrutinization of these technologies. Thus, these adverse impacts on soil and environmental sustainability created a need of sustainable agricultural production system to overcome those challenges of Indian Agriculture under changing climate scenario.

Challenges for Indian Agriculture

Though the green revolution technology enormously increased the agricultural production in India but it also enhanced the use of chemical fertilizers and pesticides to the tone of seven and 375 folds. This uncontrolled consumption of synthetic products has resulted in some devastating effects on Indian agriculture. Therefore, the internal regulation

Volume 3 – Issue 3
Online ISSN: 2582-368X
www.agriallis.com

in the biological interactions, agro-ecosystem functioning and over all environmental sustainability has been subdued by this external input-driven approach. Excessive application of synthetic agro-chemicals has led increased soil, water and environmental pollution. In a large scenario, the green revolution has led the socio-economic disparity among the Indian farming community as its favoured the large landholding farmers and agro-based industries but has negative impacts on small and marginal farming community besides the adverse impacts on water resources, environment and soil fertility (Kumari et al., 2019). Therefore, Indian agriculture is facing the following major challenges in post green revolution era:

1. Food security
2. Depletion of water resources
3. Deterioration of soil quality
4. Nutrient availability
5. Socio-economic disparity among farming community

Food Security

Food security can be defined as reliable access to sufficient quantity of nutritious food. Though, the enormous food production post green revolution has declined the undernourished population from 18.6% in 1990-92 to as low as 10.9% in 2014-16. But still many people across the country facing the food and nutritional insecurity. Thus, sustainable achievement of food security is the major economic, political, sociological and scientific challenge in the 21st century. As per the global estimates the average per capita energy requirement is 2780 kcal day^{-1}, but in the developing and under developed economies the per capita energy availability is less than 2200 kcal day^{-1}. India has performed well in achieving the goal of food security in last three decades but still the country has to achieve many more in the area of sustainable food production.

Depletion of water resources

Water is the major factor in agricultural production. The Indian agriculture is predominantly dependent on monsoon which results in uncertainity in water availability for agricultural production. Thus, canal and well irrigation systems have played a crucial role in agricultural production in Indian context. Development in canal and well irrigation systems have increased the irrigated cropped area to the tone of twofold in last 50 years. But this development has led the over exploitation of ground and surface water resources in

Volume 3 – Issue 3
Online ISSN: 2582-368X
www.agriallis.com

agricultural system and as per the reports of Ehrlich and Harte (2015) ~30% of the total freshwater withdraw from resources is used for rice cultivation across the globe while in Asian continent >45% of freshwater is utilized by flood irrigated rice crop. Therefore, the resource-intensive agriculture has impeded the continuous availability of freshwater in present changing climate scenario. The crop yield is severely influenced by water scarcity compared with other challenges and continuous exploitation of water resources will lead to rising food prices, food shortage and higher food imports by the third world countries (Arulbalachandran et al., 2017). Injudicious use of water resources has also increased the waterlogging and intensified the process of soil salinization. Therefore, proper irrigation water management, judicious use of water resources should give proper attention by the policy makers.

Deterioration of Soil Quality

Intensification of agricultural practices has first and foremost consequences on soil. Soil organic carbon (SOC) is considered as an important soil quality indicator as it directly or indirectly controls soil structure maintenance, nutrient cycling, pesticide and water retention. Enormous use of agro-chemicals in intensive farming has alarmingly declined the soil organic matter (SOM) content which is the main cause of deteriorated soil quality (Sankar Ganesh et al., 2017). Alteration in SOM quantity in soil has also led the reduced microbial diversity of soil which further has a negative impact on soil quality. As per the reports of Pal *et al*. (2015) the level of SOC Indian soils varied from 20 to 25 Gt carbon in the top one-meter soil depth, thus most of the Indian cultivable soils contains 4-8 g kg^{-1} SOC. As per an estimate the food product of 40% human population across the globe is derived by nitrogen based chemical fertilizers and therefore, the nitrogen fertilizer demands are increasing at the rate 1.7% per year (FAO, 2011). If we talk about the India and China, they alone consume the ~ 49% of total fertilizer consumption in Asia. Injudicious use of chemical fertilizers and subsequent decrease in organic manures application has led to acidification of tropical Indian soils which resulted in deterioration of soil quality and productivity. More than 60% of cultivable land has been degraded by indiscriminate use of chemical fertilizers, excess nutrient mining and multi nutrient deficiencies. Therefore, the sole application of chemical fertilizers has led reduction in crop productivity of tropical Indian soils in two ways i.e. decreased soil fertility, deteriorated soil biodiversity and nutrient use efficiency and hinder crop productivity.

Volume 3 – Issue 3
Online ISSN: 2582-368X
www.agriallis.com

Nutrient Availability

Seventeen different nutrient elements have been identified as essential plant nutrients for proper growth and development of crop plants (Sathya et al., 2016). These elements have been categorized as macro and micro nutrients based on their requirements to the crop plants. The macronutrients are further divided into primary and secondary nutrients based on their rate of consumption by the plants as the primary nutrients are consumed rapidly by the plants compared with the secondary nutrients. Thus, the primary nutrients are supplied through the straight fertilizers, while the other nutrients are available through organic manures, biological nitrogen fixation and plant residues (Sankar Ganesh et al., 2017). Tough the micronutrients are required in less quantity in comparison to macronutrients, but they are essential part of carbon, protein and lipid metabolism enzymes. Injudicious use of single nutrient based chemical fertilizers i.e. nitrogenous, phosphatic and potassic fertilizers accompanied by soil erosion and surface runoff have resulted in deficiency of secondary and micronutrients in most of the Indian soils. This multi-nutrient deficiency has led the reduction in crop productivity due to nutrient deficiency induced metabolic disturbances in the crop plants. Mobility of micronutrients is governed by several factors i.e. organic matter, pH, chemical factions of these micronutrients and their concentration and soil-plant-microbes interaction (Shukla et al., 2015). Therefore, for sustainable crop production, judicious and integrated use of synthetic fertilizers and manure, use of efficient crop varieties, improved agronomic management practices and proper soil-plant-microbes interaction is highly necessitated.

Socio-Economic Disparity among Farming Community

The Indian agriculture is highly dominated by the small and marginal farmers which accounts 88% of total farming community India. This small and marginal farming category is mostly dominated by the Schedule tribe and Schedule caste categories (Nath et al., 2018). Other than this, the small and marginal land holders cultivate on 72Mha land and contribute about 56-60% of India's total food requirement but their land holdings among the most climatically and ecologically vulnerable lands. Thus, the changing climate scenario followed by environmental degradation, hunger, poverty and land degradation has great impact on these small and marginal farmers. Shifting of Indian farmers towards mono crop and cash crop cultivation has increase the threat to long-term sustainability of Indian agriculture. In a whole, the green revolution technology alone cannot achieve the challenges of soil quality

Volume 3 – Issue 3
Online ISSN: 2582-368X
www.agriallis.com

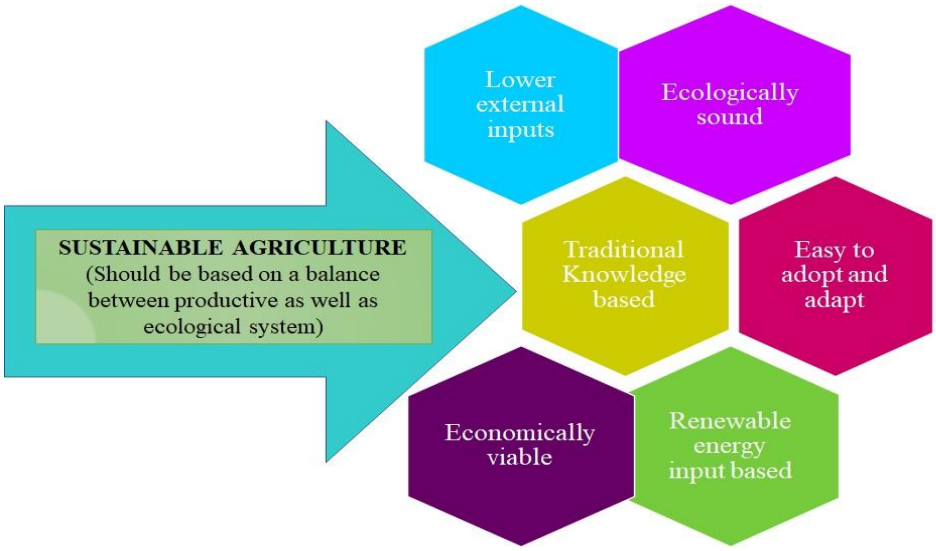
deterioration, food security and farmers' socio-economic status because of many undesirable impacts of this technology. Therefore, there is urgent need of such technologies which is ecologically sound coupled with low external inputs and traditional knowledge to meet the changing climate scenario (Srivastava *et al.*, 2016).

Sustainable Agriculture

Research studies across different parts of the India as well as the globe have proved the adverse impacts of green revolution on soil microbial biodiversity. Other than that stagnation in crop yields have been noticed in the Indo-Gangatic plains where, the green revolution technology flourished. Enormous and injudicious use of agro-chemicals has led the emission of green-house gasses from agricultural sector which resulted in global warming and climate change. Therefore, the focus of agriculture research has been shifted towards holistic natural resource management for long-term crop productivity to achieve the food security (Sathya et al., 2016). Maintenance of soil quality and soil health is an essential component for long-term crop productivity which can be achieved with the use of efficient resource conservation technologies i.e. integrated use of organic manures along with synthetic fertilizers, biofertilizers and inclusion of organic manures in the production systems. Thus, sustainable agriculture is the only way to meet the food demand of growing global population along with long-term protection of crop productivity and improved soil health (Barea 2015). As per the standard definition of sustainable agriculture as outlined by Corwin et al. (1999) "sustainable agriculture concept is predicted on a delicate balance of maximum crop productivity and economic stability, while minimizing the utilization of finite natural resources and detrimental environmental impacts." As per Tilman et al. (2002) "sustainable agriculture is the practices that meet current and future societal needs for food and fibre, for ecosystem services, and for healthy lives, and that do so by maximizing the net benefit to society when all costs and benefits of the practices are considered." The need and basis of sustainable agriculture can be understood from figure 3.

Volume 3 – Issue 3
Online ISSN: 2582-368X
www.agriallis.com

Fig. 3. Need and basis of the sustainable agriculture (Source: Singh et al., 2019)



The sustainable agriculture is the integration of traditional as well as modern scientific knowledge which is not only economically viable, easy to adopt but also ecologically sound practice which emphasize on the use of renewable energy input resources. It integrates the progressive coordination among the different stakeholders by adopting temporal adaptation and ecologically sound traditional knowledge. Environmental, social and economic sustainability are the three main pillars of sustainable agriculture. All these three pillars are adjunct in three P's framework i.e. planet-people-profit. Thus, most of the researchers have elaborated the primary goals of sustainable agriculture as (1) promotion of prosperous social livelihood of farming community, (2) minimal damage to environmental resources and promotion of environmental stewardship through improved soil quality and decreased dependency on non-renewable resources and (3) Provision of more profitable farm incomes. Sustainable agriculture integrates comprehensive range of soils, pest and nutrients management technologies i.e. crop residues, dung, biological nitrogen fixation, crop rotations, mixed cropping etc. (Mtengeti et al., 2015).These sustainable agriculture measures are beneficial for biological diversity, improved soil quality and nutrient pools, ecosystem restoration and climate resilience by decreasing the soil degradation on one hand and increasing socio-economic status of farmers on the other hand. However, subsidized rate of synthetic fertilizers and poor availability of organic nutrient sources is major constraint for shifting towards sustainable agroecosystem. Thus integrated nutrient management which combines the use of organic and inorganic inputs are being advocated in sustainable agriculture for augmenting the soil quality and nutrient pools. In a nutshell, sustainable

Volume 3 – Issue 3
Online ISSN: 2582-368X
www.agriallis.com

agriculture is basically depending on the facts of more output with less environmental resources. Recently many technologies i.e. organic farming, conservation agriculture, integrated nutrient management precision agriculture, biofertilizers etc. have been emerged for sustainability of agricultural system (Srivastava et al., 2016).

Conclusion

Though the green revolution has successfully delivered the role of food provider to the large population at a great extent. But the excess use of external inputs like synthetic fertilizers and other agrochemicals have led to degradation of natural resources and environment. In such changing climate scenario sustainable agriculture has been emerged as a suitable alternative not only to maintain the long-term crop productivity and soil health but also helps in reduction of greenhouse gas emission from the agriculture and allied sectors. Sustainable agriculture performs in a way to meet current and future societal needs for food and fibre, for ecosystem services, and for healthy lives, and that do so by maximizing the net benefit to society.

References

Arulbalachandran D, Mullainathan L, Latha S (2017) Food Security and sustainable agriculture. Sustainable agriculture towards food security. Springer, Singapore, pp 3–13

Barea JM (2015) Future challenges and perspectives for applying microbial biotechnology in sustainable agriculture based on a better understanding of plant-microbiome interactions. J Soil Sci Plant Nutr 15:261–282.

Corwin DL, Loague K, Ellsworth TR (1999) Assessing non-point source pollution in the vadose zone with advanced information technologies. In: Corwin DL, Loague K, Ellsworth TR (eds) Assessment of non-point source pollution in the vadose zone. Geophysical Monogr 108: AGU, Washington, DC, USA, pp 1–20.

Directorate of Economics & Statistics (2019) Agricultural statistics at a glance. http://eands .dacne t.nic.in/. Accessed 21 Aug 2019.

Ehrlich PR, Harte J (2015) Food security requires a new revolution. Int J Environ Stud 72:908–920. https ://doi.org/10.1080/00207233.2015.10674 68

Volume 3 – Issue 3
Online ISSN: 2582-368X
www.agriallis.com

FAO (2011) Current world fertilizer trends and outlook to 2015. Food and Agricultural Organizations of United Nations, Rome, p 41.

INECC (2010) The semi-arid region (2010). http://www.ced.org.in/ docs/inecc /aridçbookl et/Arid-3-Arids .pdf. Accessed 20 Apr 2014 International Fund for Agricultural Development (IFAD) (2012) Sustainable smallholder agriculture: feeding the world, protecting the planet. International Fund for Agricultural Development, Rome, p 12.

Kumari T, Singh R, Verma P (2019) Agriculture, forests and environmental management trinity: towards environmental sustainability and climate change mitigation. Trop Ecol. https ://doi. org/10.1007/s4296 5-019-00025 -0

Mtengeti EJ, Brentrup F, Mtengeti E, Eik LO, Chambuya R (2015) Sustainable intensification of Maize and Rice in smallholder farming systems under climate change in Tanzania. In: Lal R et al (eds) Sustainable intensification to advance food security and enhance climate resilience in Africa. Springer, Switerzerland, pp 441–465. https ://doi.org/10.1007/978-3-319-09360-4_24.

Nath AJ, Lal R, Sileshi GW, Das AK (2018) Managing India's small landholder farms for food security and achieving the "4 per Thousand" target. Sci Total Environ 634:1024–1033.

Pal DK, Wani SP, Sahrawat KL (2015) Carbon sequestration in Indian soils: present status and the potential. Proc Natl AcadSci India Sect B BiolSci 85:337–358. https ://doi.org/10.1007/s40011-014-0351-6

Sankar Ganesh KS, Sundaramoorthy P, Nagarajan M, Xavier RL (2017) Role of organic amendments in sustainable agriculture. Sustainable agriculture towards food security. Springer, Singapore, pp 111–124

Sathya A, Vijayabharathi R, Gopalakrishnan S (2016) Soil microbes: the invisible managers of soil fertility. Microbial inoculants in sustainable agricultural productivity. Springer, New Delhi, pp 1–16.

Shukla AK, Malik RS, Tiwari PK, Prakash C, Behera SK, Yadav H, Narwal RP (2015) Status of micronutrient deficiencies in soils of Haryana. Indian J Fert 11:16–27.

Volume 3 – Issue 3
Online ISSN: 2582-368X
www.agriallis.com

Singh, R., Singh, H. and Raghubanshi, A.S. (2019). Challenges and opportunities for agricultural sustainability in changing climate scenarios: a perspective on Indian agriculture. Tropical Ecology 60: 167-185.

Srivastava P, Singh R, Tripathi S, Raghubanshi AS (2016) An urgent need of sustainable thinking in agriculture—an Indianscenario. Ecol Indian 67:611–622. https ://doi.org/10.1016/j.ecolind.2016.03.015

Tilman D, Cassman KG, Matson PA, Naylor R, Polasky S (2002) Agricultural sustainability and intensive production practices. Nature 418:671–677. https://doi.org/10.1038/natur e0101 4.