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SUSTAINABLE INTENSIFICATION OF AGRICULTURAL SYSTEMS IN IRAN FOR ADAPTATION TO CLIMATE CHANGE: OPPORTUNITIES AND CHALLENGES

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Attaining sustainable food security in Iran, as a country located on an arid and semi-arid region requires overcoming many challenges including limited basic resources (water and arable land), improving food safety and health and increasing productivity of agroecosystems as well as reconstructing market and affordability to food. Climate change has further threatened country's capabilities for sustainability of agricultural systems. Reconsideration for intensive farming due to diminished quality and quantity of water, soil, and biodiversity resources which are caused by long time conventional practices is a necessity for providing sustainability of agroecosystems in Iran. Food security, however, should not be declined in the process; so, we need a new paradigm of "sustainable intensification" which integrates food security and meanwhile ecological sustainability of these systems. Sustainable intensification is a prerequisite of adaptation for climate change in Iran, as adaptation needs to reduce water consumption and increase water use efficiency (WUE), optimize soil tillage and management and maximize productivity of whole production chain. This would be done in triple steps including reducing input consumption, replacing conventional inputs and practices by integrated and sustainable ones and finally recreating and redesign climate- resilient agroecosystems. Opportunities and challenges of the duty are reviewed in the current work.

Keywords: *food security, resilience, sustainability, Iran.*

Introduction

Iran is the second largest country in the Middle East, with an area of 1.65 million km^2. It has been a center for the evolution of agriculture, people engaged in agriculture first settled here some 10000 years ago [5]. Since Iran spans a wide range of latitudes and longitudes, it also has a diverse range of physiography, climate, vegetation and biological productivity. Rangelands constitute 35%, deserts and degraded lands 21%, forests 7.4%, agricultural land 14.4% and urban areas, lakes and other lands 2.2% of the total area of the country [8]. Over 18 million ha of land are used for agriculture, producing 100 MT of food, from field crops to horticultural products, for a population of 80 million. Currently, 3.4 million farmers in Iran cultivate 18.5 million ha [7]. Different types of farming systems and land tenure can be found throughout the country, from commercial to subsistence farms. Statistics published by FAO [4] showed that agriculture in Iran is consuming 17.6 kg N ha^{-1}, 7.5 kg P ha^{-1} and 1.3 kg K ha^{-1} annually. Data on country food security indicate that 5.5% of population is experiencing different kinds of food insecurity and hunger. Table 1 draws a comprehensive picture of agriculture in Iran.

Agriculture has a long history in Iran. It has been argued that dryland farming first evolved in the western part of the country about 10000 years ago, simultaneously with the domestication of goats and sheep [5]. Farmers have managed their traditional agroecosystems for centuries by focusing on sustaining long-term yields rather than maximizing yields in the short term. Land management was based on practices and knowledge associated with self-reliance and family units within communities. This system of land use evolved on the basis of the following structural and functional principles [8]:

- Consideration of high species numbers and structural diversity in time and space (vertical and horizontal organization of crops and animals);
- Exploitation of a wide range of microenvironments (soils, water, temperature, altitude and fertility);
- Recycling practices for materials and wastes;
- Reliance on biological interdependencies;
- Reliance on local resources plus human and animal energy (low input technology);
- Reliance on local crop varieties and incorporation of wild plants and animals;
- Implementation of collective production activities based on self-sustained and self- sufficient communities.

Table 1

Iran metadata on agriculture [4]

	1990	2000	2014
The Setting			
Population, total (mln)	54.6	65.9	78.5
Population, rural (mln)	24.6	23.7	23.9
Govt expenditure on ag (% total outlays)		3	1.4
Area harvested (mln ha)	14	13	22
Cropping intensity ratio	0.2	0.2	
Water resources (1000 m^3/person/year)	2	2	2
Area equipped for irrigation (1000 ha)			9553
Employment in agriculture (%)		23	21.2
Employment in agriculture, female (%)		16.7	30.6
Fertilizer, nitrogen (kg of nutrients per ha)		52.5	17.6
Fertilizer, phosphate (kg of nutrients per ha)		21.6	7.5
Fertilizer, potash (kg of nutrients per ha)		6.3	1.3
Energy consump, power irrigation (mln kWh)	2	219	1688
Agr value added per worker (constant US$)	2122	2558	3313
Food security dimensions			
Dietary energy supply (kcal/pc/day)	2950	3045	3287
Average dietary energy supply adequacy (%)	135	130	138
GDP per capita (US$, PPP)	8679	10694	15090
Improved water sources (% pop)	92.2	94.1	95.9
Food supply			
Food production value, (mln $)	12210	17582	25588
Agriculture, value added (% GDP)	19	14	10
Food exports (mln $)	345	904	3970
Food imports (mln $)	2211	2484	9668
Net trade (mln $)			
Cereals	-981	-1465	-4387
Fruits and vegetables	262	452	1305
Meat	-290	-33	-506
Dairy products	-161	-49	188
Fish	37	14	178
Environment			
Forest area (%)	7	7	7
Terrestrial protect areas (% total land area)	6	6	7
Biofuel production (1000 kt of oil eq.)	4	13	1
Net GHG emission from AFOLU (CO2 eq. Mt)	37	43	38

Climate Change in Iran and Its Effects on Agricultural Production

Iran, like other parts of the world has been affected by climate change. Koocheki et al. [11] using 40 year meteorological data of 34 cities studied the effects of climate change on Iran agriculture. According to predictions of two general circulation models (GCMs), results showed that annual mean temperature on 2050 will increase 3.5–4.5°C. Results also revealed that annual precipitation will decrease on 2050 comparing current situation by 7–14%. Results clearly show that growing season will increase and freezing-free days will decrease in all studied areas. It means that in all part of country, even in cold areas, growing season will increase and improve the condition for crop production. However, it should be mentioned that longer growing season without appropriate soil water content would not be any advantage for crop growth and yield; therefore, actual growing season will be decreased in most parts of the country which imposes another limitation for dryland crop production. As shown in Figure 1, duration of dry season will be 21–30 days longer in different parts of the country.

Alizadeh and Kamali [1] showed that 2, 4 and 6°C temperature increase in Mashhad Plain will increase net irrigation demand of current cropping pattern by 6, 11 and 17%, respectively. Results of Ebrahimi [2] in Khorrasan Razavi Province showed that water demand of the region at 2050 will increase 22% comparing current demand.

Koocheki and Nassiri Mahallati [10] applying General Fluid Dynamic Lab (GFDL) showed that on 2050 comparing current condition, the yield of 4 staple crops including wheat, maize, chick pea and sugar beet will be decreased; the highest and lowest decreased was reported for sugar beet and chick pea, respectively (Figure 2). Koocheki and Kamali [9] studied the effects of climate change on rainfed wheat production in Iran and reported that at 2025 and 2050 yields will be lower by 16–24% and 22–32%, respectively.

Adaptation *vs.* Maladaptation to Climate Change

There are two main policy responses to climate change: mitigation and adaptation. Mitigation addresses the root causes, by reducing greenhouse gas emissions, while adaptation seeks to lower the risks posed by the consequences of climatic changes. Both approaches will be necessary, because even if emissions are dramatically decreased in the next decade, adaptation will still be needed to deal with the global changes that have already been set in motion.

Climate change adaptation helps individuals, communities, organizations and natural systems to deal with those consequences of climate change that cannot be avoided. It involves taking practical actions to manage risks from climate impacts, protect communities and strengthen the resilience of the economy. Adaptation can involve gradual transformation with many small steps over time, or major transformation with rapid change.

The adaptation strategies are intended to inform and assist communities in identifying potential alternatives. They are illustrative and are presented to help communities consider possible ways to address anticipated current and future threats resulting from the changing climate. In particular, it is important to note [3]:

- The strategies presented are not a comprehensive or exhaustive list of resiliency or adaptation ac-

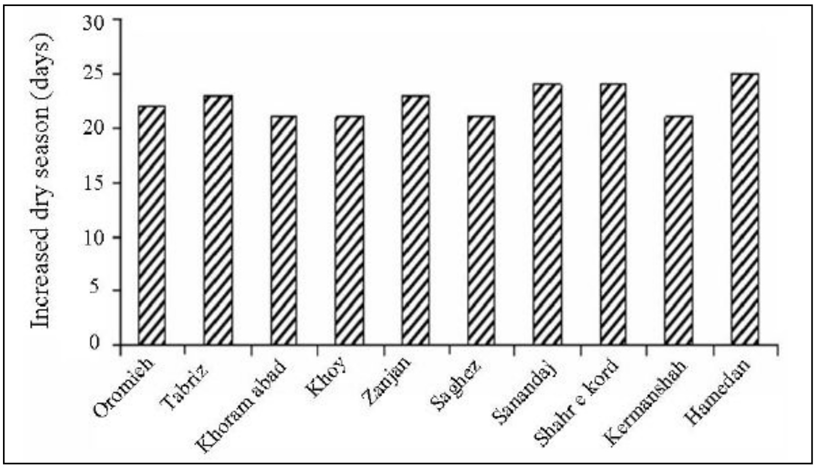

Figure 1. Predicted increase in the length of dry season for year 2050 compare to current conditions in the main rainfed production regions of the country, changes were predicted using GFDL model [11]

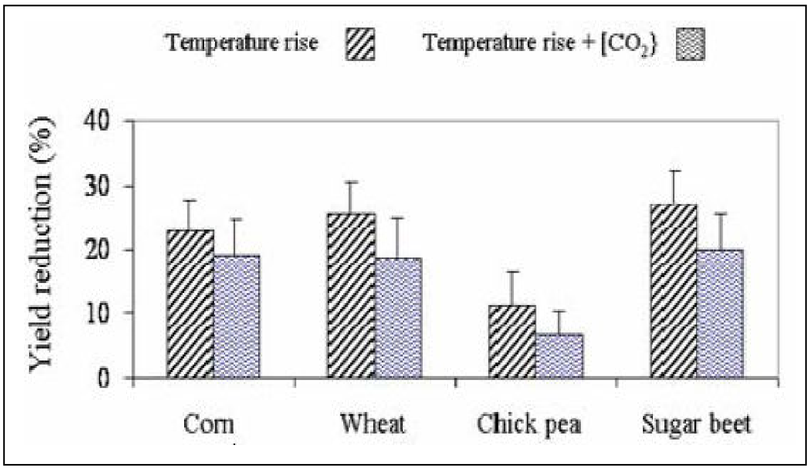

Figure 2. Predicted yield reduction in the studied crops for the year 2050 compared to current yields, yield are predicted using SUCROS model under temperature rise and temperature rise + increased CO_2 concentration. Vertical bars show SE of regions [10]

tions that may be relevant.

- None of the provided alternatives are likely to be appropriate in all circumstances; the appropriateness of each alternative should be considered in the local context for which it is being considered.
- The potential strategies are largely drawn from EPA and other federal resources. Before adopting any particular strategy, it should be considered in the context provided by the primary source document from which it originated. Source document(s) are indicated.
- The presented strategies should not be relied on exclusively in conducting risk assessments, developing response plans, or making adaptation decisions.

As mentioned earlier, Agriculture is a major part of the climate problem; it currently generates 11 to 29% of total greenhouse gases emissions. Therefore, Climate-Smart Agriculture (CSA) aims to make the agriculture sector better-suited to handle the challenges of a changing climate by sustainably increasing agricultural productivity; helping food systems adapt and building their resilience; and reducing GHG emissions. This is what we call "adaptation to climate change". However, there is always a devastating danger of accepting and application of "maladaptation" mechanisms which are defined as false and pseudo-solutions for problems. Indeed, maladaptation refers to adaptations which are neither appropriate nor sustainable in a specific condition.

According to its definition, sustainable agriculture is a "site-specific" paradigm which implies there is not a general rule for everywhere. In other words, adaptation in an area may be maladaptation in another area according to sustainability criteria. There are many cases of maladaptation in agriculture of Iran during last decades. In the case of water and irrigation, digging deep well which has resulted in severe water shortage is a maladaptation to drought and water stress. Conventional tillage in vulnerable and low-organic content soils of country is another maladaptation for soil management and finally introduction of hybrid seeds and high-demand varieties is another maladaptation to country need for more food production. So, good governance for management of climate change and minimizing its effects on agriculture, environment and natural resources requires "sustainable adaptation" that is formulated in the concept of sustainable intensification.

Sustainable Intensification: Sustainable Adaptation to Climate Change in Agriculture

Sustainable intensification has been defined as a form of production wherein "yields are increased without adverse environmental impact and without the cultivation of more land" [6]. It provides a framework for exploring what mix of approaches might work best based on the existing biophysical, social, cultural and economic context and a growing body of work is starting to emerge that explores what implementation might look like in practice.

Food outputs by sustainable intensification have been multiplicative– by which yields per hectare have increased by combining the use of new and improved varieties and new agronomic– agroecological management ...and additive – by which diversification has resulted in the emergence of a range of new crops, livestock or fish **[13]**. It should be mentioned that none of the components of this paradigm are new. They comprise techniques of ecological and genetic intensification, within enabling environments created

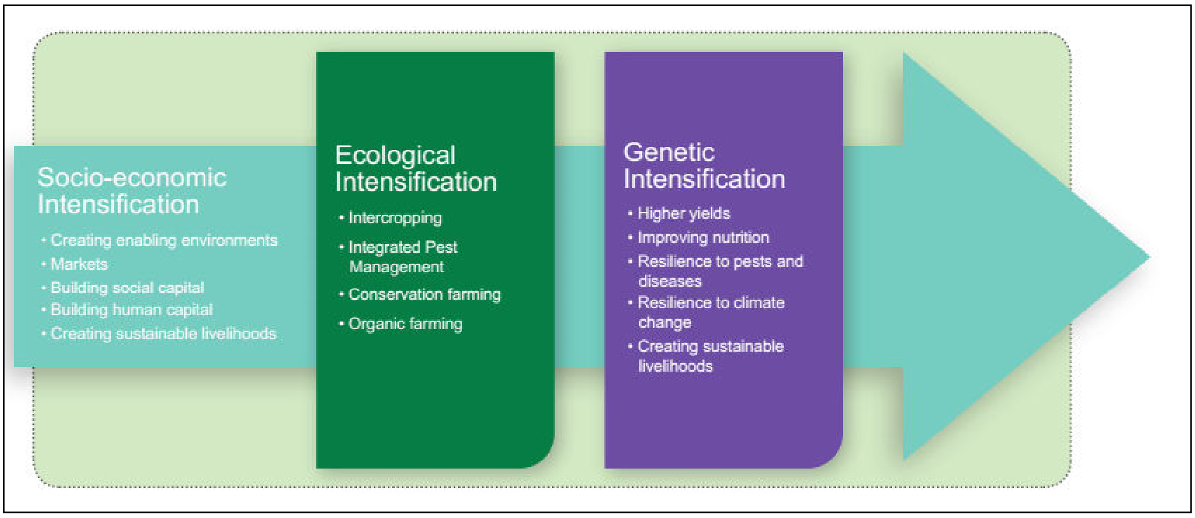

Figure 4. The practical approaches to Sustainable Intensification [14]

by processes of socio-economic intensification. What is new in this approach is the way in which they are combined as a framework to find appropriate solutions to world's food and nutrition crisis. The theoretical model for sustainable intensification is shown in Figure 3. Defined in this way, sustainable intensification is an ambitious objective but is achievable if we focus on being [14]:

- ***Prudent***, in the use of inputs, particularly those which are scarce, are expensive and/or encourage natural resource degradation and environmental problems;
- ***Efficient***, in seeking returns and in reducing waste and unnecessary use of scarce inorganic and natural inputs;
- ***Resilient***, to future shocks and stresses that may threaten natural and farming systems;
- ***Equitable***, in that the inputs and outputs of intensification are accessible and affordable amongst beneficiaries at the household, village, regional or national level to ensure the potential to sustainably intensify is an opportunity for all.

Sustainable intensification looks for optimizing returns on inputs while preserving resources. It is increasingly relying on new technologies like satellite imagery, information technology and geospatial tools. For example, they may analyze and plot in detail the nutrient levels in different parts of their fields and then use tractors equipped with satellite positioning systems to apply different fertilizer mixes in accordance with soil needs in specific locations.

In this paradigm, soil and nutrient management should be based on efficient application and uptake of nutrients from chemical, biologic as well as organic resources. Between 1960 and 2000 the efficiency of N use for global cereal production decreased from 80%

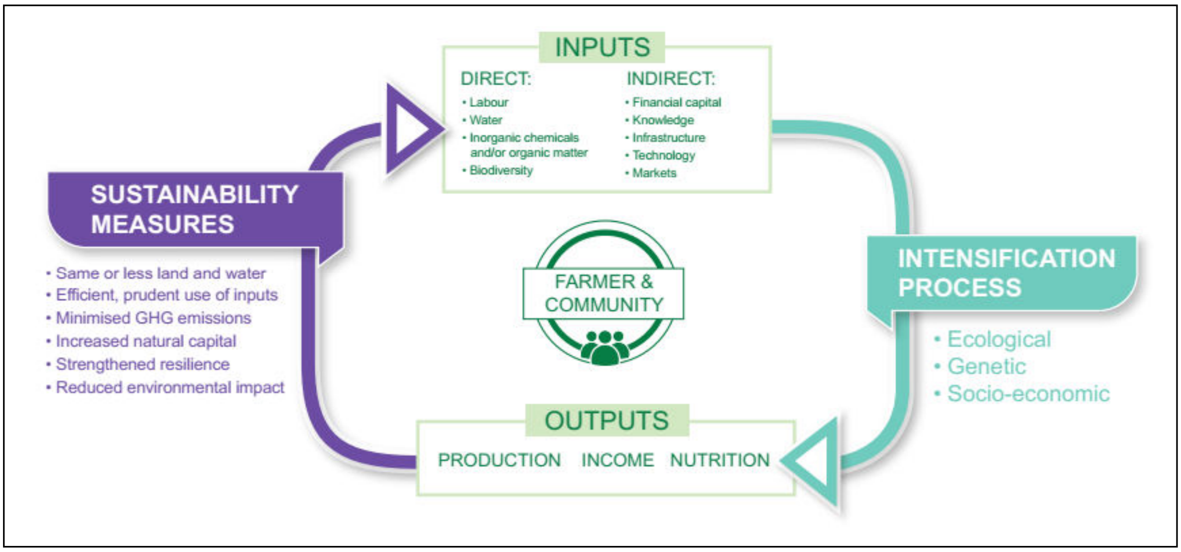

Figure 3. The theoretical model for sustainable intensification [14]

to 30%. Farmers in countries like Iran need to strike the right balance between managing soil organic matter, fertility and moisture content and the use of fertilizers. One highly efficient and intrinsically sustainable approach is the technique of micro dosing developed to both minimize the application of and over reliance on inorganic fertilizer and to improve nutrient use efficiency and protection against drought. The same principle can be applied to use of herbicides that, far too often, are sprayed relatively indiscriminately, killing not only weeds but other wild plants and sometimes damaging the crops themselves. Applying precision farming techniques simultaneously addresses the challenge of combating serious weed problems in Africa – such as *Striga* (or witchweed), which sucks nutrients from the roots of maize, sorghum, millet, cowpea and other crops – while minimizing any unintended or undesirable environmental impacts [14].

As with nutrients, water has to be available for crop uptake in the right amounts and at the right time, as water stress during growth results in major yield reductions for most crops. In these and other examples, the interconnectedness of water, soil and nutrient conservation is critical. The most successful systems are those that provide water, nutrients and a supportive soil structure in a synergistic fashion. Figure 4 explains the practical approaches to sustainable intensification for countries like Iran.

Conclusion

Applying sustainable intensification principles in agroecosystems for adaptation to climate change is a gradual and step by step process. Transition to sustainable intensification in Iran does not affect agricultural production and farmer income. Furthermore, it does not push farmers to quit inputs and practices of intensive agriculture. Finally, design and management of agroecosystems based on this paradigm need to careful consideration of site-specificity of any agroecosystem. Governmental support and access to education will guarantee the success of sustainable intensification globally [12].

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