Economic modeling of climate-smart agriculture in Iran

Zahra Ardakani*, Fabio Bartolini*, Gianluca Brunori*

DOI: 10.30682/nm1901c
Jel codes: C39, N55, Q54

Abstract

Global warming is the immediate consequence of increased greenhouse gasses emission. Agriculture is a significant source in terms of greenhouse gasses emission and on the other hand, the main sector in terms of producing food. As global food demand grows, the share of agriculture in the total greenhouse gasses emission will rise too. Therefore, agriculture needs to cut the greenhouse gasses emission. A response to the two important issues today, i.e. achieving food security and reducing greenhouse gasses emission is climate-smart agriculture. According to the Paris Agreement, an international effort to reduce greenhouse gasses emission, Iran has to decrease 12 percent of its greenhouse gasses emission by 2050, which all sectors have to contribute. Since the pathway to define strategies, is to explore the challenges; in this study, a seemingly unrelated regression technique has been used to model the climate-smart agriculture in Iran. Three main sub-sectors of agriculture; i.e. crops, livestock, and aquatics production, have been considered in the model to find the role of them in delivering food security and emitting greenhouse gasses. The findings show livestock and aquaculture sectors have had a positive significant impact in achieving food security. On the other hand, these sectors have had a positive significant effect on the emitting greenhouse gasses. Cropping system was not found to have a significant role in achieving food security and emitting greenhouse gasses in Iran although the expected signs (+) has been confirmed by the model. New research to explore appropriate technical and behavioral innovations needs to do on the specific-product-sector to be climate-friendly and sustainable. On the consumers hand, an encouragement to a more healthy diet with more vegetable, where is possible, also can reduce emissions. Finally, the key message from the assessments is the future legislative outlines for mitigation, adaptation and resource management as well as consumer behavior for how agriculture can deal with climate change.

Keywords*: Paris Agreement, Climate-Smart Agriculture, Seemingly Unrelated Regression, Iran.*

1. Introduction

Global warming, a critical issue today, is defined as an increasing in the average of the temperature on Earth (Venkataramanan and Smitha, 2011; Palanichamy, 2009), which is caused to happen frequent storms, droughts and floods (Venkataramanan and Smitha, 2011; Bretschger, 2017; Modarres *et al.*, 2016). Some evidences of world climatic warming show increasing in the global annual average surface temperature and is predicted to rise by 1.3 to 1.7°C above the pre-industrial average by 2050 (Deng *et al.*, 2017). Human activities such as burning fossil fuels, clearing forests and growing crops (Agrawal, 2011) increase the level of greenhouses gasses

* Department of Agricultural, Food and Environmental Economics, University of Pisa, Pisa, Italy.
Corresponding author: zahra.ardakani@gmail.com

in the atmosphere (Venkataramanan and Smitha, 2011; Roop Ganesh, 2011). Carbon dioxide, methane, chlorofluorocarbons and nitrous oxides act such as a greenhouse effect (Palanichamy, 2011; Venkataramanan and Smitha, 2011) and contribute (Żukowska *et al*., 2016) to an immediate consequence (FAO, 2008), which is global warming (Vongvisessomjai, 2010; Roop Ganesh, 2011), and change the climate (Rajadurai and Raveendran, 2011). The Intergovernmental Panel on Climate Change (IPCC) is warning that the global climate is changing and expected to continue in the near future (IPCC, 2014; Notenbaert *et al.*, 2017).

Simultaneously, food and nutrition security is another critical issue (Deng *et al.*, 2017). Food and Agriculture Organization (FAO) estimates that farmers will have to produce 70 percent more food to meet the needs of the world expected population of 9.1 billion people by 2050 (FAO, 2009; Notenbaert *et al.*, 2017). According to the fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC), the identified key climate change risks are linked to food and nutrition security (FAO, 2016a). E.g., decreasing in the agricultural productivity (directly), and increasing in the agricultural prices (indirectly) (FAO, 2017a; FAO, 2017b; FAO, 2017c; Esham *et al*., 2017) are the known effects. A reduction of 3.2 percent in the global food availability (Luo *et al*., 2017) is predicted. This is largely a result of the direct and mostly negative impacts of rising temperatures, changes in precipitation patterns and increased frequency of extreme events on the productivity of crops, livestock, forestry, fisheries, aquaculture and ecosystems (FAO, 2017a).

The Paris Agreement signed in December 2015 by more than 100 countries, set the goal to reduce greenhouse gasses emission by 80 percent from 2005 levels by 2050 to limit global temperature rise to lower than 2°C by 2100. Reducing greenhouse gasses emission from agriculture is thus critical to meeting the Paris Agreement emission targets (Subbarao *et al*., 2017; Deng *et al.*, 2017). The Paris Agreement also endorsed the importance of reducing greenhouse gasses emission from deforestation and forest degradation, and encouraged countries to take action in this area (FAO, 2017b). Following the Paris Agreement, these contributions will transform into nationally determined contributions, which will be an important roadmap for directing future technical and policy support for the agriculture sector (Chandra *et al*., 2016). The adoption of the Paris Agreement on climate change reflects broad acknowledgment that stringent climate policies are beneficial on a global scale. At the same time, individual countries are reluctant to adopt the necessary policy measures because they fear negative consequences for their domestic economy (Bretschger, 2017). Iran is one of the signed countries in the agreement.

World Bank categorizes Iran as an upper-middle-income country, with a total GDP of 425 billion US dollars, 28th in the world, and a population of more than 78 million people which is estimated around 88 and 100 million in 2025 and 2050, respectively. According to the Central Bank of Iran, agriculture sector accounts for over 10 percent of the GDP, near 20 percent of the labor force and 20 percent of the non-oil exports in the economy of Iran. Due to the differences in climate conditions and temperature variations in the country, Iran can produce a varied range of vegetation. According to the latest information available in FAOSTAT in 2014, cropping system in Iran is producing a wide-ranging of grains, fruits, and vegetables, which the main crops include cereals (wheat, barely, rice, and maize), fruits (grapes, dates, melons, apples, oranges), vegetables (tomatoes, potatoes, onions, and cucumbers), and legumes (chickpeas, peas, lentils, and rapeseed) etc. Poultry, cattle, sheep, and goat are the main production of livestock sector in Iran according to the data available in FAO website in 2014. Statistical Yearbook of the Iranian Fisheries Organization in 2014 reports carp, trout, shrimp, and caviar are the main aquatic production in Iran. Furthermore, Iran is the largest producer of pistachio, saffron and barberry in the world. Iran is ranked as an important agricultural producer for several agricultural commodities among the top 20 producers in the world (WFP, 2016).

Agriculture sector in Iran, faces several challenges in achieving food security. For instance, climate change and climatic shocks are one of the main issues that has made agriculture sector vulnerable in delivering food and nutrition security (Ardakani *et al*., 2017). To better understanding of the causality between food security, climate events and human activities and explore the opportunities to agri-environmental goals (Elbehri *et al.*, 2017), the main objective of the study is to find the most significant agricultural sectors i.e. crops, livestock, and aquatics in delivering food security in Iran and on the other hand in emitting greenhouse gasses.

The rest of the paper is structured as follows. The section to follow introduces the literature review on the field of climate-smart agriculture. Section 3 introduce using seemingly unrelated regression model in climate-smart agriculture conception. Section 4 presents the data and reports a descriptive statistics of the dataset used in the study. Section 5 brings together the statistical and econometrics results and section 6 discusses the empirical results. Moreover, the final section concludes the study and extant the implications.

2. Literature Review

Agriculture is an essential for both developed and developing countries to increase food production and deliver food security goals (Chandra *et al*., 2016) and on the other hand, agriculture contributes to emit greenhouse gasses (FAO, 2017b; Żukowska *et al.*, 2016), which are caused to change the climate. On the other hand, agriculture is definitely the most affected sector by the negative effects of climate change, especially regarding the quantity and quality of the products (Alrusheidat *et al.*, 2016).

Agriculture has been discussed to a wide range of policy interventions that seek to achieve agri-environment-related objectives (Troost *et al.*, 2015; Chandra *et al*., 2016) i.e. delivering food security and preventing global warming. Therefore, agricultural policies play an important role to support sustainability in the courtiers, developed or developing (FAO, 2017b; FAO, 2017c).

It is important an integration of mitigation and adaptation agri-environmental initiatives (Chandra *et al.*, 2016) to reduce greenhouse gasses emission per unit of food (FAO, 2017b). Mitigation and adaptation are two well-known behaviors for decreasing climate change negative impacts. Mitigation strategies are associated with reducing greenhouse gasses emission through management practices such as organic farming (Moradi *et al.*, 2013), deforestation (Żukowska *et al.*, 2016), agroforestry (Thornton, 2010) etc. Then adaptation strategies are associated with minimizing the potential negative impacts of climate change while maximizing opportunities for adjustment such as crop rotation (Moradi *et al*., 2013), diversification (Żukowska *et al.*, 2016), diet improving (Thornton, 2010) etc. Agriculture needs to adapt and mitigate the negative impacts of climate change for the sustainable development goals (Luo *et al*., 2017). Climate-smart agriculture is one response to the challenges faced by agriculture due to climate change (Long *et al*., 2016).

Climate-smart agriculture or climate-friendly agriculture (Żukowska *et al*., 2016) is introduced as a sustainable approach to promote adaptation-mitigation synergies (FAO, 2017c; Chandra *et al*., 2017) and minimize the negative impacts by integrating the concerns for food security (Arslan *et al*., 2017; Żukowska *et al*., 2016). Climate-smart agriculture, as defined and presented by FAO in 2010 (FAO, 2010; Żukowska *et al*., 2016), aims at sustainably increasing food security and incomes, adapting and building resilience to climate change, and reduce and or remove greenhouse gasses emission, where possible (FAO, 2017b; Chandra *et al*., 2016; FAO, 2017c; Sain *et al*., 2017). According to this definition, climate-smart agriculture has three dimensions i.e. adaptation, mitigation, and production (FAO 2010; Chandra *et al*., 2017). Therefore, any practice or technology that supports at least one of the three pillars; productivity, resilience and mitigation in agriculture under climate change and variability can be a climate-smart agriculture technology (Thierfelder *et al*., 2017; Khatri-Chhetri *et al*., 2015).

Iran is currently self-sufficient in vegetables and nuts and furthermore, there are almost no import of chicken meat, cheese and milk. But at the same time, there is a significant import of red meat, butter, fish, fruits, wheat and rice; and self-sufficiency regarding to these products is not expected to be achieved in the near future. Also it should be noted that roughly 70 percent of the raw ingredients for animal feed is imported from out of the country. The self-sufficiency rate is 50 percent lately (WFP, 2016). The government policy on self-sufficiency to ensure food security is to be increasingly challenged in the coming years, due to a number of reasons such as water shortage and salinization of land (Danish Agriculture and Food Council, 2017). Looking at the changes in precipitation (250 millimeter in average per year) and temperature (18 centigrade in average per year) indices reveals climate warming in Iran (Modarres *et al*., 2016; Moradi *et al*., 2013) as well as happening in the floods and droughts have been very seriously increasing (Modarres *et al*., 2016). Iran is using 97 percent of surface waters and 70 percent of the ground water, whereas the international benchmark for surface water use is 40 percent. The agricultural sector is responsible for more than half of the total water consumption in Iran. However, despite the high level of water consumption in the agriculture sector, it only contributes to around 10 percent of the GDP. These figures indicate the high level of inefficiency in the use of water within the agricultural sector in Iran (Danish Agriculture and Food Council, 2017). Iran has focused on the food self-sufficiency to reach food security with no enough attention to the water-use efficiency (Karandish and Hoekstra, 2017) and water scarcity as a major impact of climate warming.

According to the Paris Agreement, an internationally effort to tackle the climate warming, Iran has accepted to decrease greenhouse gasses emission by 4 percent over 2021 to 2030 and existing a potential to reduce the emissions to 12 percent if there is financial and technological supports to remove the negative impacts of climate change in the country. Understanding of the barriers and incentives will aid the design and implementation of interventions that can overcome barriers (Notenbaert *et al*., 2017). As an attempt to support the Paris Climate Agreement and addressing issues related to assessing and modelling of agriculture and food security under climate change, in this study, we try to run a model to integrate the goals of climate-smart agriculture. In an econometric equation system, a seemingly unrelated equation regression, we point out the roles of main Iranian agricultural sectors i.e. crops, livestock, and aquatics production in delivering food security and emitting greenhouse gasses emission in the country.

3. Methodology

In econometrics, the seemingly unrelated regression *(SUR)* or seemingly unrelated regression equations *(SURE)* model, proposed by Arnold Zellner in (1962), is a generalization of a linear regression model that consists of several regression equations, each having its own dependent variable and potentially different sets of exogenous explanatory variables. Each equation is a valid linear regression on its own and can be estimated separately, which is why the system is called seemingly unrelated, although the term seemingly related would be more appropriate, since the error terms are assumed to be correlated across the equations. The model can be estimated equation-by-equation using standard ordinary least squares *(OLS)*. Such estimates are consistent, however generally not as efficient as the seemingly unrelated regression method, which amounts to feasible generalized least squares with a specific form of the variance-covariance matrix. When the error terms are in fact uncorrelated between the equations, the seemingly unrelated regression is in fact equivalent to OLS (so that they are truly unrelated) and when each equation contains exactly the same set of regresses on the right-hand-side (Zellner, 1962).

Modelling the climate-smart agriculture implies a set of equations that may be related not because they interact, but because their error terms are related (Haroll Kokoye *et al*., 2013). Therefore, the appropriate econometrics technique to capture correlation among error terms when we have continuous dependent variables is the seemingly unrelated regression *(SUR)* model (Zellner, 1962; Jaleta *et al*., 2015). In this study, based on the objectives of climate-smart agriculture i.e. delivering food security and reducing greenhouse gasses emission, a system of equations can be defined as the following formulations:

$$y_1 = \beta_0 \pm \beta_1 x_1 \pm \beta_2 x_2 \pm \beta_3 x_3 + \varepsilon_1 \quad (1)$$

$$y_2 = \alpha_0 \pm \alpha_1 x_1 \pm \alpha_2 x_2 \pm \alpha_3 x_3 + \varepsilon_2 \quad (2)$$

A seemingly unrelated regression model is used to estimate the coefficient of the system, jointly (Jaleta *et al.*, 2015). In the above system β and α stand the coefficients of explanatory variables, which are crops, livestock, and aquatics production (x_1, x_2, and x_3 respectively) and ε_1 and ε_2 are the error terms. Dependent variables i.e. y_1 and y_2 represents a proxy of food availability and greenhouse gasses, respectively. Because of the existence of high correlation between the related indicators of food availability and greenhouse gasses a Principle component analysis *(PCA)* is used to present a component according to the explained variance (Li and Yang, 2016; Qu *et al.*, 2016; Cumming and Wooff, 2007) as a proxy for the dependent variables.

4. Data

Table 1 shows the descriptive statistics of the data, which are used in the study. Two main goals of climate-smart agriculture concept i.e. delivering food security through increasing agricultural productivity and mitigating greenhouse gasses emission through adapting agricultural activities to be climate-friendly have been considered as the dependent variables in the empirical model. Food availability, the first dimension of food security, is a multi-dimensional concept that is defined by different indicators. We have used the defined indicators of food availability, which are available on the Food and Agriculture Organization (FAO) website. Greenhouse gasses emission can be defined by different gasses, which the main are carbon dioxide, methane, and nitrous oxide. The main sources of greenhouse gasses emission in agriculture are Carbon dioxide, methane emissions, nitrous oxide emissions (Żukowska *et al.*, 2016). According to the goal of the study, which tries to find the role of different agricultural sectors in delivering food security and the most challenges of agricultural sectors in emitting greenhouse gasses, the production of crops, livestock, and aquatics have been considered as the explanatory variables in the empirical mod-

Table 1 - Descriptive statistics of the variable used in the empirical analysis. Period: 1990-2014.

Variables	*Mean*	*S.D.*	*Min*	*Max*
Dependent variables: *Food availability indicators:*				
Average dietary energy supply adequacy (%)	130.64	4.89	125	139
Average value of food production ($)	298.40	37.53	225	358
Share of dietary energy supply derived from cereals, roots and tubers (%)	57.20	3.77	51	62
Average protein supply (gr/caput/day)	83.20	1.97	78	86
Average supply of protein of animal origin (gr/caput/day)	21.20	2.59	17	25
Greenhouse gasses indicators:				
Carbon dioxide (mt-co2)	398.81	138.30	180.22	621.79
Methane (mt-co2e)	76.32	13.49	51.78	97.71
Nitrous oxide (mt-co2e)	22.81	2.47	18.17	27.56
Explanatory variables:				
Crops production (mt)	58.01	10.77	40.13	74.41
Livestock production (mt)	8.21	1.77	5.16	10.85
Aquatics production (mt)	0.11	0.10	0.02	0.34
Other variables:				
Precipitation (mm)	17.63	3.19	11.04	23.23
Temperature (°C)	17.83	0.57	16.16	18.91

Source: FAO, CAIT, and authors' specification.

el. The data come from the official websites of FAO and CAIT from 1990 to 2014 for Iran.

5. Results

To find a proxy for each of the dependent variables in the system (food availability and greenhouse gasses), a principle component analysis has been used. According to the results of principle component analysis of food availability indicators, 83 percent (eigenvalue = 4.142) of the total variance of food availability indicators has been explained by component one. So component one has been predicted to consider as a proxy for food availability. The correlation between component 1 of food availability and the single indicators is reported in Table 2. On the other hand, 90% (eigenvalue = 2.686) of the total variance of greenhouse gasses indicators has been explained by component one, which is caused to predict component one for the proxy of greenhouses gasses. Table 3 reports the correlation between component one and the greenhouse gasses indicators.

Graph 1 presents the trend of food security index (constructed by principle component analysis) over the studied period. As this graph shows, food security has been improved in this period in Iran but on the other hand, Graph 2 shows the emission of greenhouse gasses during the period, which is increasing. As we can see, the emissions have increased that shows economic sectors are not climate-smart in the country (confirmed by the statistical models reported in the Tables 5 and 6 of the Annex A). As the agricultural activities stand a source of greenhouse gasses emission and responsible for about 14 percent of global greenhouse gasses emission (Żukowska *et al.*, 2016), it can be said that agricultural sector including crops, livestock, and aquatics sectors do not use enough climate-friendly practices and technologies in Iran.

Table 2 - The correlation between component 1 and the single indicators of food availability.

Variables	*Component 1*
Average dietary energy supply adequacy (%)	-0.3095
Average value of food production ($)	0.4831
Share of dietary energy supply derived from cereals, roots and tubers (%)	-0.4771
Average protein supply (gr/caput/day)	0.4586
Average supply of protein of animal origin (gr/caput/day)	0.4826

Source: authors' specification.

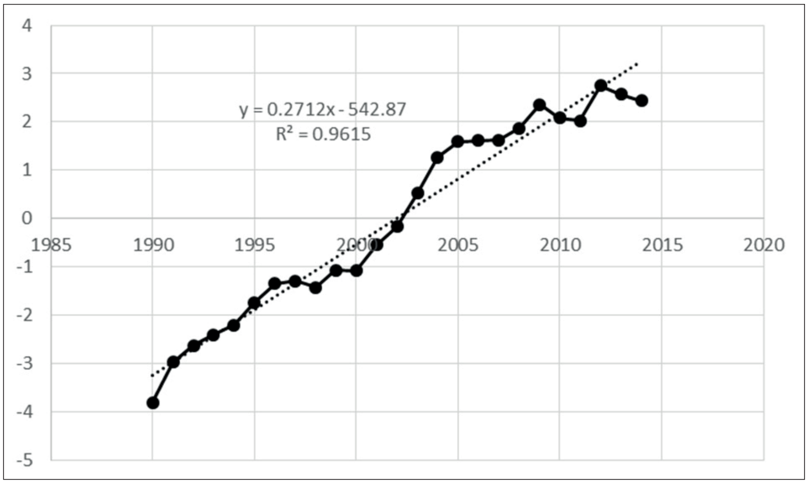
Table 3 - The correlation between component 1 and the single indicators of greenhouse gasses.

Variables	*Component 1*
Carbon dioxide (mt-co2)	0.5807
Methane (mt-co2e)	0.5992
Nitrous oxide (mt-co2e)	0.5511

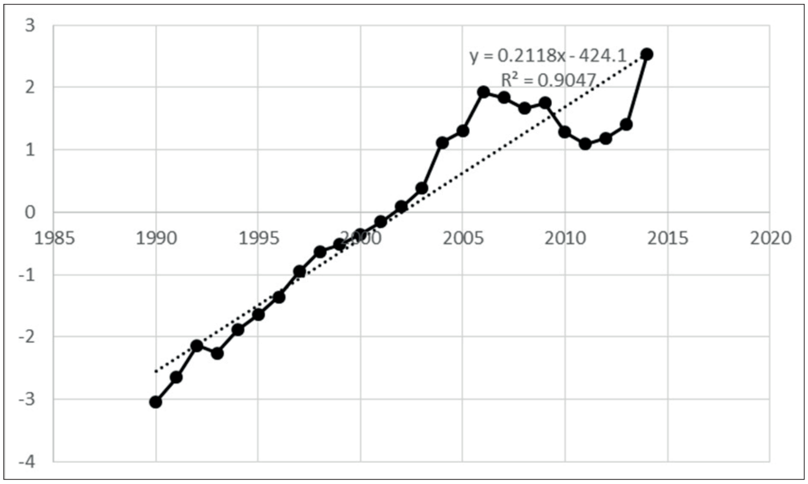
Source: authors' specification

Since the pathway to define appropriate policies is to find the challenges, barriers, and incentives, in this paper we try to make an econometric model of climate-smart agriculture in Iran using the seemingly unrelated regression model. In the conception of climate-smart agriculture, it is seen two main goals i.e. increasing agricultural productivity to improve food security, and reducing the greenhouse gasses emission to prevent the climate change. Therefore, these two main goals has been considered as our dependent variables in the equations system. The three main sectors of agriculture in delivering food security and emitting greenhouse gasses i.e. crops, livestock, and aquatics have been considered as our explanatory variables in the equations system to explore the role of them in delivering food security and on the other hand in emitting greenhouse gasses in Iran. The results of the estimation of the seemingly unrelated regression model has been reported in Table 4. In the pre-estimation step, Dickey-Fuller test has been done to test unit root of the variables used in the estimation.

The statistical results of the empirical model point out the explanatory variables in both two equations have received expected signs (+). According to the first equation that is delivering food security, livestock and aquatics production are statistically significant but crops production



Graph 1 - The trend of improving food security in Iran (index).
Source: FAO and authors' specification.



Graph 2 - The trend of emitting greenhouse gas in Iran (index).
Source: CAIT and authors' specification.

is not. Livestock and aquatics production have significant role in delivering food availability and then food security. On the other hand, in the second equation that is emitting greenhouse gasses of agriculture sector, the main sectors in emitting greenhouse gasses are livestock and aquatics production, again. Therefore, although livestock and aquatics production have an important role in the delivering of food availability in the country but they have another important role in emitting greenhouse gasses.

6. Discussion

Climate change is a global phenomenon (Agrawal, 2011) that can be determined by the two main factors i.e. temperature and precipitation (Agrawal, 2011; Modarres *et al.*, 2016). The trend of changing in temperature and precipitation in Iran during the studied period (1990-2014), shows climate warming is happening in the country (Graphs 3 and 4 in the Annex B.) which is expected to affect agricultural practices adversely. Climate warming i.e. less precipitation and long dry seasons affected by emitting of greenhouse gasses, which can reduce agricultural production and yields, increase livestock mortality, decrease milk production, crop failures and soil erosion (FAO, 2016b). As Iran, with less than one-third of the global average precipitation, is one of the water-scarce areas in the world, so adaptation of agriculture sector is imperative in the country. Without considering adaptation and mitigation

Table 4 - The statistical results of seemingly unrelated regression of climate-smart agriculture.

Variables	*Food availability*		*Greenhouse gasses*		
	Coef.	*P > z*	*Coef.*	*P > z*	
Crops production	0.0001	0.916	0.0005	0.691	Number of obs = 25 Breusch-Pagan test: Chi2 (1) = 5.098 Prob = 0.0240 Mean VIF = 2.38
Livestock production	0.0702	0.000	0.0688	0.000	
Aquatics production	0.8014	0.000	0.4494	0.000	
Intercept	-9.8867	0.000	-7.275	0.000	
R- squared	0.973		0.951		
Chi2	907.63		488.57		
Prob	0.000		0.000		

Source: authors' specification.

strategies, the impacts of climate change on agriculture will be substantial.

Our final results in Table 4 indicated, cropping system is not capable in delivering food availability. The Iranian agricultural sector is using antiquated farming techniques which reduces the yields (Danish Agriculture and Food Council, 2017). So cropping system needs innovations and interventions to be more productive according to soil and water scarcity in the country and at the same time climate-friendly. The application of technologies for effective use of inputs such as energy, fertilizer, water, seeds, feeds and pesticides should be supported to improve the input-output ratio in the agricultural production (FAO, 2017c) and increase the partial productivities; then environmental sustainability, where possible (Kimaro *et al.*, 2016).

Estimates indicate that 45 percent of total greenhouse gasses emission attributed to agriculture are from animal production (Valenti *et al.*, 2015). As our results show too; even though livestock and aquatics production systems are capable in delivering food availability but they must be innovated for climate-friendly practices and technologies, where is possible. For instance, dietary guidelines can help in shaping a more sustainable and health-enhancing food system by providing guidance on dietary patterns that are not only coherent with nutritional requirements but also generate fewer environmental impacts (FAO, 2017c).

According to the Ministry of Agriculture in Iran, the main development challenges faced by the country in the agricultural and rural sector are: lack of arable land and water; food security and self-sufficiency, low productivity, poverty in rural areas, and high dependence of feed imports. National plans and policies like the 5ht National Development Plan are essentially aiming to respond to these challenges by including climate change related issues, but the attention is not enough. Improving agricultural productivity based on current technology, strengthening research for new technologies, and policy reforms are taken in the Iranian national plans to adapt and mitigate the effects of climate changing (Karimi *et al.*, 2018). All ministries and organizations will be required to develop their own respective plans to deal with climate change by preparing of greenhouse gasses measurements of their activities; promoting of mitigation policies; assessing the vulnerability of each sector to the impact of climate change; assessing the technological needs for mitigation and adaptation strategies; research and education programs to raise the awareness of policy-makers; and enhancing their overall capabilities to screen the climate change.

4. Conclusion

Climate-smart agriculture is an approach that brings together agricultural practices, policies, institutions and financing in the context of climate change and needs to be coordinated through national planning processes that implement properly climate change action plans. In this study, we have modelled climate-smart agriculture conception in Iran. According to the findings, livestock and aquatics sectors are the main challenges in emitting greenhouse gasses in the agriculture sector while they have affective role in delivering food security. Cropping systems are not effective in delivering food security. Mitigating and adapting strategies to climate change requires information, education, and technology transfer. (Alrusheidat *et al.*, 2016 and Davis, 2009). Therefore, appropriate technical and behavioral investments in a food-friendly-climate system is necessary in the country to increase partial productivities (land, labor, water, capital, etc.). First of all, a specific-context (multidisciplinary) research should be done in a specific product for a specific innovation. Then, climate-resilient technologies and practices for the management of crops, livestock and aquatic at the farm level need to identify the interactions between food security, adaptation and mitigation. Lastly, the agricultural sector in Iran needs a comprehensive modernization and an update with the newest technology that can reduce the consumption of natural resources (in particular water) and increase effectively and productivity of Iranian agriculture.

To conclude, a common climate policy is needed to build a sustainable earth (Rajadurai and Raveendran, 2011) by mitigating the greenhouse gasses emission from the atmosphere (Agrawal, 2011) and reducing the negative impacts of climate change (Bretschger, 2017). Generally, two strategies are used in the process of climate-friendly agriculture management, noting that agricultural practices can mitigate climate change (reduction of greenhouse gasses emission), or adapting agriculture to the already noticeable changes (development of soil and water quality, sustainable agronomy, animal cross-breeding, or crop rotation) (Żukowska *et al.*, 2016).

References

Agrawal A., 2011. Effect of global warming on climate change, flora and fauna. *J. Ecophysiol. Occup. Hlth*, 11: 161-174.

Alrusheidat J., Hammour W.A. and Aliaafreh S., 2016. Climate change adaptation and technology transfer: the path to disaster risk reduction in the arid and semi-arid zones. The case of Jordan. *New Medit*, 15(1): 2-6.

Ardakani Z., Bartolini F. and Brunori G., 2017. Food and Nutrition Security in Iran: Application of TOPSIS Technique. *New Medit*, 16(1): 18-28.

Arslan A., Cavatassi R., Alfani F., Mccarthy N., Lipper L. and Kokwe M., 2017. Diversification Under Climate Variability as Part of a CSA Strategy in Rural Zambia. *The Journal of Development Studies* (http://dx.doi.org/10.1080/00220388.2017.1293813).

Bretschger L., 2017. Climate policy and economic growth. *Resource and Energy Economics*, 49: 1-15.

Chandra A., Dargusch P., McNamara K.E., Caspe A.M. and Dalabajan D., 2017. A Study of Climate-Smart Farming Practices and Climate-resiliency Field Schools in Mindanao, the Philippines. *World Development*: in press.

Chandra A., McNamara K.E., Dargusch P., Damen B., Rioux J., Dallinger J., Bacudo I., 2016. Resolving the UNFCCC divide on climate-smart agriculture. *Carbon Management*, 7(5-6): 295-299.

Cumming J.A. and Wooff D.A., 2007. Dimension reduction via principal variables. *Computational Statistics & Data Analysis*, 52: 550-565 (DOI:10.1016/j.csda.2007.02.012).

Danish Agriculture and Food Council, 2017. *The agriculture and food market in Iran, Opportunities and challenges for Danish companies*, The Royal Danish Embassy in Tehran.

Davis K., 2009. *Agriculture and climate change. An agenda for negotiation in Copenhagen for food, agriculture, and the environment. The important role of extension systems*. Focus 16, Brief 11.

Deng A., Chen C., Feng J., Chen J., Zhang W., 2017. Cropping system innovation for coping with climatic warming in China. *The Crop Journal*, 136-150.

Elbehri A., Challinor A., Verchot L., Angelsen A., Hess T., Ouled Belgacem A., Clark H., Badraoui M., Cowie A., De Silva S., Erickson J., Joar Hegland S., Iglesias A., Inouye D., Jarvis A., Mansur E., Mirzabaev A., Montanarella L., Murdiyarso D., Notenbaert A., Obersteiner M., Paustian K., Pennock D., Reisinger A., Soto D., Soussana J-F., Thomas R., Vargas R., Van Wijk M. and Walker R., 2017. *FAO-IPCC Expert Meeting on Climate Change, Land Use and Food Security: Final Meeting Report*, January 23-25, 2017, FAO HQ Rome.

Esham M., Jacobs B., Sunith Rohitha Rosairo H. and Boubacar Siddighi B., 2017. Climate change and food security: a Sri Lankan perspective, *Environ Dev Sustain* (DOI: 10.1007/s10668-017-9945-5).

FAO, 2008. Climate Change and Food Security: A Framework Document, Rome.

FAO, 2009. State of Food and Agriculture. FAO, Rome (http://www.fao.org/docrep/012/i0680e/i0680e.pdf).

FAO, 2010. Climate-smart agriculture: Policies, practices and financing for food security, adaptation and mitigation, Rome, Italy: Food and Agriculture Organization of the United Nations.

FAO, 2016a. FAO Capacity Development, Strengthening individual and institutional capacities to adapt to climate change in Lao PDR, Rome, Italy: Food and Agriculture Organization of the United Nations.

FAO, 2016b. Planning, implementing and evaluating Climate-Smart Agriculture in Smallholder Farming Systems, The experience of the MICCA pilot projects in Kenya and the United Republic of Tanzania, Rome.

FAO, 2017a. Addressing Agriculture, Forestry and Fisheries in National Adaptation Plans, By Kaisa Karttunen, Julia Wolf, Claudia Garcia and Alexandre Meybeck, Rome, Italy: Food and Agriculture Organization of the United Nations.

FAO, 2017b. The future of food and agriculture, Trends and challenges, Rome, Italy: Food and Agriculture Organization of the United Nations.

FAO, 2017c. Strengthening Sector Policies for Better Food Security and Nutrition Results, Climate Change, Rome, Italy: Food and Agriculture Organization of the United Nations.

Haroll Kokoye S.E., Yabi J.A., Tovignan S.D., Yegbemey R.N. and Nuppenau E., 2013. Simultaneous modelling of the determinants of the partial inputs productivity in the municipality of Banikoara, Northern Benin. *Agricultural Systems*, 122: 53-59 (http://dx.doi.org/10.1016/j.agsy.2013.08.002).

IPCC, 2014. Summary for policymakers. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge-New York: Cambridge University Press, 1-32.

Jaleta M., Kassie M. and Erenstein O., 2015. Determinants of maize stover utilization as feed, fuel and soil amendment in mixed crop-livestock systems, Ethiopia. *Agricultural Systems*, 134: 17-23 (http://dx.doi.org/10.1016/j.agsy.2014.08.010).

Karandish F. and Hoekstra A.Y., 2017. Informing National Food and Water Security Policy through Water Footprint Assessment: the Case of Iran. *Water*, 9(831): 1-25 (DOI: 10.3390/w9110831).

Karimi V., Karami E. and Keshavarz M., 2018. Climate change and agriculture: Impacts and adaptive responses in Iran. *Journal of Integrative Agriculture*, 17(1): 1-15 (DOI: 10.1016/S2095-3119(17)61794-5).

Khatri-Chhetri A., Aggarwal P.K., Joshi P.K. and Vyas S., 2015. Farmers' prioritization of climate-smart agriculture (CSA) technologies. *Agricultural Systems*, 151: 184-191 (http://dx.doi.org/10.1016/j.agsy.2016.10.005).

Kimaro A.A., Mpanda M., Rioux J., Aynekulu E., Shaba S., Thiong'o M., Mutuo P., Abwanda S., Shepherd K., Neufeldt H., and Rosenstock T.S., 2016. Is conservation agriculture 'climate-smart' for maize farmers in the highlands of Tanzania? *Nutr Cycl Agroecosyst*, 105: 217-228 (DOI: 10.1007/s10705-015-9711-8).

Li Y. and Yang H., 2016. Performance of the restricted almost unbiased type principal components estimators in linear regression model. *Stat Papers* (DOI: 10.1007/s00362-016-0821-4).

Long T.B., Blok V. and Coninx I., 2016. Barriers to the adoption and diffusion of technological innovations for climate-smart agriculture in Europe: evidence from the Netherlands, France, Switzerland and Italy. *Journal of Cleaner Production*, 112: 9-21 (http://dx.doi.org/10.1016/j.jclepro.2015.06.044).

Luo X-S., Muleta D., Hu Z., Tang H., Zhao Z., Shen S., Lee B-L., 2017. Inclusive development and agricultural adaptation to climate change. *Current Opinion in Environmental Sustainability*, 24: 78-83 (http://dx.doi.org/10.1016/j.cosust.2017.02.004).

Modarres R., Sarhadi A. and Burn D.H., 2016. Changes of extreme drought and flood events in Iran. *Global and Planetary Change*, 144: 67-81.

Moradi R., Koocheki A., Nassiri Mahallati M. and Mansoori H., 2013. Adaptation strategies for maize cultivation under climate change in Iran: irrigation and planting date management, *Mitig Adapt Strateg Glob Change*, 18: 265-284 (DOI: 10.1007/s11027-012-9410-6).

Notenbaert A., Pfeifer C., Silvestri S. and Herrero M., Targeting, out-scaling and prioritizing climate-smart interventions in agricultural systems: Lessons from applying a generic framework to the livestock sector in sub-Saharan Africa. *Agricultural Systems*, 151: 153-162.

Palanichamy A.P., 2011. Global warming-Greenhouse effect. *Indian Journal of Science and Technology*, 4(3): 204-206.

Qu J., Qin S., Liu L., Zeng J. and Bian Y., 2016. A hybrid study of multiple contributors to per capita household CO2 emissions (HCEs) in China, *Environ Sci Pollut Res*, 23: 6430-6442 (DOI: 10.1007/s11356-015-5856-x).

Rajadurai S. and Raveendran P., 2011. Environmental accountability for a sustainable Earth. *Indian Journal of Science and Technology*, 4(3): 355-360.

Roop Ganesh P.H., 2011. Global warming/greenhouse effect. *Indian Journal of Science and Technology*, 4(3): 219-222.

Sain G., Loboguerrero A.M., Corner-Dolloff C., Lizarazo M., Nowak A., Martínez-Barón D. and Andrieu N., 2017. Costs and benefits of climate-smart agriculture: The case of the Dry Corridor in Guatemala. *Agricultural Systems*, 151: 163-173 (http://dx.doi.org/10.1016/j.agsy.2016.05.004).

Subbarao G.V., Arango J., Masahiro K., Hooper A.M., Yoshihashi T., Ando Y., Nakahara K., Deshpande S., Ortiz-Monasterio I., Ishitani M., Peters M., Chirinda N., Wollenberg L., Lata J.C., Gerard B., Tobita S., Rao I.M., Braun H.J., Kommerell V., Tohme J., Iwanaga M., 2017. Genetic mitigation strategies to tackle agricultural GHG emissions: The case for biological nitrification inhibition technology. *Plant Science*: in press.

Thierfelder C., Chivenge P., Mupangwa W., S. Rosenstock T., Lamanna C. and Eyre X.J., 2017. How climate-smart is conservation agriculture (CA)? - its potential to deliver on adaptation, mitigation and productivity on smallholder farms in southern Africa. *Food Sec*. (DOI: 10.1007/s12571-017-0665-3).

Thornton P.K., 2010. Livestock production: recent trends, future prospects. *Philosophical Transaction of the Royal Society B*, 365: 2853-2867 (DOI: 10.1098/rstb.2010.0134).

Troost C., Walter T. and Berger T., 2015. Climate, energy and environmental policies in agriculture: Simulating likely farmer responses in Southwest Germany. *Land Use Policy*, 46: 50-64.

Valenti W., Nicolino Peixoto Henares M. and Mitsue Kimpara J., 2015. Greenhouse emissions from aquaculture. *Global aquaculture advocate*, 52-53: January/February 2015.

Venkataramanan M. and Smitha 2011. Causes and effects of global warming. *Indian Journal of Science and Technology*, 4(3): 226-229.

Vongvisessomjai S., 2010. Effect of global warming in Thailand, Songklanakarin. *Journal of Science Technology*, 32(4): 431-444.

WFP 2016. *Food and Nutrition Security in Iran, a summary report*, WFP Iran country office: World Food Programme.

Zellner A., 1962. An efficient method of estimating seemingly unrelated regressions and tests of aggregation bias*. J. Am. Stat. Assoc*. 57: 348-368.

Żukowska G., Myszura M., Baran S., Wesołowska S., Pawłowska M. and Dobrowolski L., 2016. Agriculture vs. Alleviating the Climate Change. *Problemy Ekorozwoju - Problems Of Sustainable Development*, 11(2): 67-74.

Annex A

Table 5 - The Effects of Economic sectors on Emitting Greenhouse Gasses in Iran.

Variables	*Greenhouse gasses*		
	Coef.	*P > t*	
Agriculture	5.77e-13	0.991	Number of obs = 25 F (4, 20) = 30.51 Prob F = 0.000 Mean VIF = 11.89
Industry	1.09e-11	0.420	
Services	1.42e-11	0.260	
Natural Resources	1.17e-11	0.249	
Intercept	-4.813032	0.000	
R-squared	0.8592		
Adj R-Squared	0.8310		

Source: authors' specification.

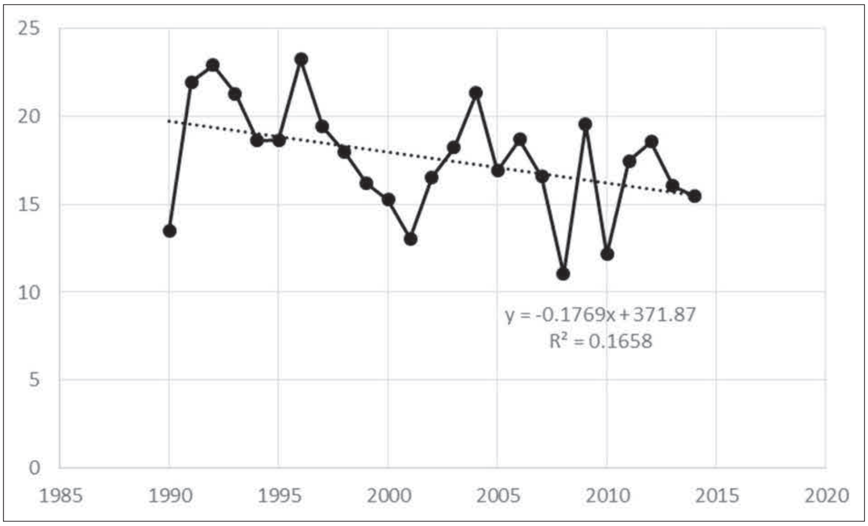
Table 6 - The Effects of Economic sectors on Emitting Greenhouse Gasses in Iran.

Variables	*Greenhouse gasses*		
	Coef.	*P > t*	
GDP	1.60e-11	0.000	Number of obs = 25 F (1, 23) = 121.13 Prob F = 0.000
Intercept	-5.365008	0.000	
R-squared	0.8404		
Adj R-Squared	0.8335		

Source: authors' specification.

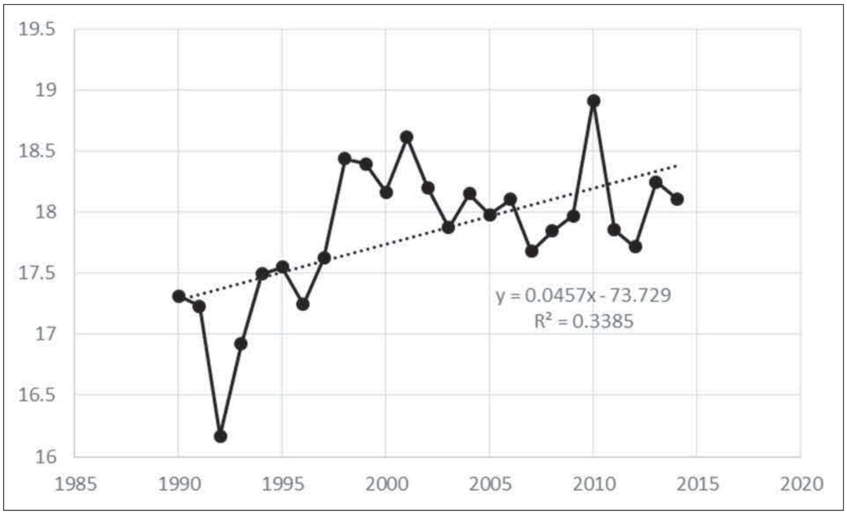
Annex B

Graph 3 - The precipitation trend in Iran (millimeter).



Source: World Bank and authors' specification.

Graph 4 - The temperature trend in Iran (centigrade)



Source: World Bank and authors' specification.