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An exploratory analysis of the impact of climate change on Macedonian agriculture

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Using a mixed input-output framework, this study examined potential changes in sector output and water requirements at national level in Macedonia arising from climate change. By defining three climate change scenarios and exogenously specifying the warming shocks for five key agricultural sub-sectors, the direct and indirect effects on the economy in terms of output and water demand were quantified. In general, the results indicated that except for cereals and grapes, agricultural production would benefit from the low climate change scenario, while there would be negligible effects on the rest of the economy. In contrast, the medium and high climate change scenarios would most likely negatively affect agriculture, with severe losses in grape, apple and cereal production, but again with low effects on other economic sectors. These results on the potential economic and physical impacts of climate change can help decision makers formulate future adaptation measures for the Macedonian agriculture sector.

Keywords: agriculture, climate change, crop production, mixed input-output model, water consumption

JEL codes: C00, C55, D57, O13, Q15

1. Introduction

Climate change has become an important issue that has potential impacts on water resource availability and consequently on agriculture, as water is a key input for crop and livestock production. Climate change thus has potential impacts on national economies, particularly in countries where agriculture is a key sector (Ciscar, 2012). Future climate change impacts in Europe will differ significantly depending on region, but with a severe decline in crop production in the Mediterranean and Continental regions of southern Europe as a result of a shorter growing period, accompanied by increased temperature and decreased rainfall (Iglesias *et al.*, 2012).

In the Republic of Macedonia[1] (hereafter 'Macedonia'), agriculture plays an important role in the national economy. In the period 2005-2011, its contribution to national GDP was about 11% on average, while it employed a significant proportion (20%) of the total available labor force (SSO, 2012). In Macedonia, the rural population represents around 43% of the total population[2]. Thus, (semi)subsistence farming in Macedonia will most likely be affected by future warming effects of climate change, which will amplify the vulnerability of its low income farmers who earn less than USD 5 per day (Sutton *et al.*, 2013).

A reduction in yields resulting from climate change, and consequently in farm income, is likely to occur in Macedonia. On a national level, three different major climate types prevail, resulting in the existence of three agro-ecological zones (AEZ), namely Mediterranean, Continental and Alpine (Aladzajkov, 1974). The Alpine type is somewhat marginal for the territory of Macedonia (see Appendix 1), covering only 4% of total area, but the Mediterranean and Continental zones represent 35% and 61% of total area, respectively (MAFWE, 2012). Hence, Macedonian agriculture is vulnerable to any climate change events (Iglesias *et al.,* 2012). Regarding temperature, within the climate types there are significant seasonal temperature variations resulting in hot summers and cold winters. Mean summer temperature ranges from 20.6 to 24.3^{o}C and winter temperature from 0.9 to 4.9^{o}C (World Bank, 2014), but it can reach highs of 45.7^{o}C (summer 2007) and lows of 30.4^{o}C (winter 1993) (MOEPP, 2008). Temperature variations are also followed by an uneven temporal and spatial distribution of precipitation, but with more favorable conditions in the western

1. Macedonia's constitutional name is the Republic of Macedonia. Within the United Nations system, it is being provisionally referred to as "the former Yugoslav Republic of Macedonia – FYROM" (UNSC Resolution 817/1993).
2. Total population in Macedonia in 2011 is estimated to be around 2.05 million (MAFWE, 2012).

part of the country (World Bank, 2010). Regarding precipitation, the annual amount ranges from 400 mm to about 1000 mm, with an average of 733 mm (*ibid*). Climate change projections by Bergant (2006) indicate that the average temperature will increase by 1°C and 1.9^{o}C by 2025 and 2050, respectively. In addition, due to temperature increases, the mean precipitation for corresponding periods is projected to decline by 3% and 5%, respectively, increasing the likelihood of more arid or drier climate conditions in Macedonia. Sutton *et al.* (2013) concluded that such increased aridity will lead up to 50% crop losses for all irrigated agriculture in the Crna River basin by the 2040s (Appendix 1). Moreover, in the period 1961-2003 there was already a noticeable decline in river flow in all Macedonian water basins (MOEPP, 2006). This, combined with a likely decrease in future precipitation, will induce even greater water scarcity.

Water scarcity can be mitigated by modernization in irrigation schemes to ensure efficient water use. However, neglect or poor maintenance by the water management authorities has caused a deterioration in the functioning of already old irrigation schemes (build in the 60s and 70s) (Cornish *et al.,* 2004). In addition, many farmers have adopted the practice of punching holes in the authority's concrete channels and irrigate without paying (Gorton *et al.,* 2009). Therefore, reduced income for suitable irrigation system maintenance results in high water losses in water supply systems (up to 40%) accompanied by soil erosion and water quality issues (MAFWE, 2010). The distribution of irrigated area in Macedonia is being similar over the years 2004-2011. On average the largest proportion is being occupied by cereals (32%), grapes (27%) and fodder (14%), followed by vegetables (11%), fruit and industrial crops (8%) (MAFWE, 2012). However, as a consequence of the technical, financial, and institutional issues explained above the irrigated area in Macedonia is currently declining and the infrastructure is deteriorating.

A potential long-term decline in water resources, combined with the irrigation issues the farmers are facing, is likely to lead to an increasing competition for water demanded from other sectors of the Macedonian economy, especially during the summer, when water use is highest. It is thus imperative that this issue be considered in strategies aimed at achieving sustainable agriculture and sustainable water management. Due to the interlinkages between the agriculture sector and the rest of the economy, climate change impacts may lead to direct or indirect variations in the outputs of other sectors and, consequently, their water requirements.

Given the above considerations, the empirical work presented in this paper attempts to answer the following questions:

- What are the implications of climate change for Macedonia's agriculture sector and the rest of its economy?
- What are the resulting water requirements, given the climate change impacts?
- Where will the impacts matter the most?

The method chosen for the analysis was an environmentally extended version of an input-output (IO) model developed by Leontief (1970), combined with a mixed model approach and water accounts. The advantage of this modelling approach is that it allows the so-called "backward linkage" effect to be investigated from a supply side perspective, whereby a reduction in agricultural output due to climate change impacts will reduce the demand for farm inputs. This in turn will trigger a whole series of indirect effects for other economic sectors, which will have to adjust their output to the new lower level of activity (Roberts, 1994).

In order to distinguish the exact implications of climate change, the agriculture sector was disaggregated into several sub-sectors, whereas it is generally considered as a single industry in most previous IO analysis. Understanding the impacts of climate change variability and measuring the resulting outcomes for agriculture and other sectors of the Macedonian economy could provide insights to policy makers tasked with developing and designing future adaptation measures for the country's agriculture sector to mitigate the impacts of climatic change.

2. Conceptual framework

2.1. Modelling procedure

An IO model is defined as a linear model of all intersectoral relationships of an economy in static production technical relations (Miller and Blair, 2009). The usual model developed by Leontief (1936) takes the following form:

$$x_i = a_{i1}x_1 + a_{ii}x_i + \ldots + a_{in}x_n + f_i \quad \text{or} \quad X = AX + F \tag{1}$$

where X is a column vector of total output production; A denotes a matrix of direct technical coefficients of production ($a_{ij} = z_{ij} / x_j$, with z indicating the transactions between sectors); and F

represents a column vector of the final demand for goods by each sector. Household and government consumption, as well as capital investment and exports, belong to this column vector.

The changes due to climate change shocks on agricultural output were investigated using a mixed model approach. As argued above, the application of a mixed model framework is useful when the aim is to model exogenous changes in output and the associated relative changes in the output of other sectors. Steinback (2004) reviewed some previous empirical studies applying a mixed IO model. In most of these the main focus was on agriculture (Roberts, 1994; Tanjuakio *et al,* 1996; etc.), for which the output was considered to be an exogenous component.

Using equation (1), a mixed IO model with three sectors, where one of the sector's output is treated as being fixed, *i.e.*, an exogenous component (in this case x_1), takes the following form:

$$\begin{aligned} -f_1 &= a_{12}x_2 + a_{13}x_3 + a_{11}x_1 - x_1 \\ x_2 &= a_{22}x_2 + a_{23}x_3 + f_2 + a_{21}x_1 \\ x_3 &= a_{32}x_2 + a_{33}x_3 + f_3 + a_{31}x_1 \end{aligned} \tag{2}$$

Rewriting and re-ordering the right-hand side gives:

$$\begin{aligned} -f_1 - a_{12}x_2 - a_{13}x_3 &= (a_{11} - 1)\, x_1 \\ x_2 - a_{22}x_2 - a_{23}x_3 &= a_{21}x_1 + f_2 \\ x_3 - a_{32}x_2 - a_{33}x_3 &= a_{31}x_1 + f_3 \end{aligned} \tag{3}$$

From equation (3), it can be seen that the items x_1, f_2 and f_3 serve as exogenous drivers for the three respective sectors. Note that f_2 and f_3 are zero. In matrix notation, this becomes:

$$\begin{bmatrix} -1 & -a_{12} & -a_{13} \\ 0 & 1-a_{22} & -a_{23} \\ 0 & -a_{32} & 1-a_{33} \end{bmatrix} \begin{bmatrix} f_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} a_{11}-1 & 0 & 0 \\ a_{21} & 1 & 0 \\ a_{31} & 0 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ f_2 \\ f_3 \end{bmatrix} \tag{4}$$

Thus, solving the mixed IO model as a function of the exogenously specified column vector in equation (4) permits investigation of the impact of the supply-driven shock upon the agriculture sector due to climate change-related variations in temperature and precipitation:

$$\begin{bmatrix} f_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} -1 & -a_{12} & -a_{13} \\ 0 & 1-a_{22} & -a_{23} \\ 0 & -a_{32} & 1-a_{33} \end{bmatrix}^{-1} \begin{bmatrix} a_{11}-1 & 0 & 0 \\ a_{21} & 1 & 0 \\ a_{31} & 0 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ f_2 \\ f_3 \end{bmatrix} \tag{5}$$

2.2. Disaggregation procedure

In most published national IO tables, agriculture is considered as a single economic sector that includes the products of hunting and other related agricultural services. However, a significant novel aspect of the present study was disaggregation of agriculture into several sub-sectors important for the Macedonian economy, through the development of an appropriate IO table.

The importance of disaggregating agriculture was highlighted in a study by Hristov *et al.* (2012), which showed that Macedonian agriculture is a key water-consuming sector, with direct intensive water consumption of around 38% of total national demand, imposing significant pressure on national freshwater resources. A comprehensive understanding of the agricultural consumption patterns at sectoral level is important but also will provide greater transparency of vulnerability regarding climate change. The national water endowment is directly related to rainfall. Because the proportion of irrigated land in Macedonia is currently very small but also declining, a negative impact of future climate change on crop output can be expected in almost all agricultural sectors and regions due to the decrease in annual rainfall, with longer dry periods followed by droughts.

Another reason why disaggregation is important is because there are major discrepancies in the recent data on irrigated area in Macedonia. Two different reports state very different values, *e.g.*, according to the 2008 Annual Agricultural Report (MAFWE, 2009), the area of irrigated land in Macedonia over the period 2004-2008 remained stable at around 21 000 ha. In contrast, the Agricultural Census (SSO, 2007a) reported a more than three-fold greater area of irrigated land (Table 1). This discrepancy can jeopardize the reliability of research results.

Therefore, obtaining a detailed picture of agriculture sector interactions at disaggregated level and of climate change variations is important, because further insights may be conveyed to the policy makers responsible for sustainable water management and climate change adaptation measures.

[Table 1]

Here the agriculture sector was disaggregated into 11 sub-sectors using the Lindberg and Hansson (2009) disaggregation procedure. Besides the 2005 IO table for Macedonia (SSO, 2008), data on the economic flows to each agricultural production enterprise obtained from the Common Agricultural Policy Regionalized Impact model (CAPRI)[3]; the EUROSTAT data on economic accounts for agriculture; the Farm Monitoring Survey (FMS)[4] on farm performance; and papers and reports published by the State Statistical Office (SSO) in Macedonia were used in the disaggregation procedure (Figure 1).

[Figure 1]

Sub-sectoral outputs were calculated based on the EUROSTAT agricultural economic accounts. Micro-level farm data are scarce and of insufficient quality, but the FMS farm data on income, crop- and livestock-specific costs and gross margins (Martinovska-Stojcheska *et al.*, 2008 and 2011) and the CAPRI data on trade and operating costs helped us calculate the flows between the agriculture sector and other sectors in the Macedonia's IO table. The total demand for products by households was determined using the SSO (2007b) data on expenditure by agricultural, mixed and non-agricultural households on the most important products originating from the sub-sectors.

Information on the area of irrigated land was combined with figures on crop water requirements (CWR) per hectare (ha) calculated specifically for Macedonia by Hoekstra and Hung (2002) and Iljoski's (1990) crop level estimates in order to construct the water accounts at disaggregated agriculture sub-sector level. Data on the proportion of irrigated crops within the main categories listed in the 2010 Annual Agricultural Report (MAFWE, 2011) were also important for the water accounts at disaggregated level. Regarding the livestock sectors, data on the water requirements per day for each group as reported in Galev and Arsovski (1990) were used.

3. More information about CAPRI may be found at: http://www.capri-model.org/dokuwiki/doku.php?id=start
4. The Farm Monitoring System (FMS) is an annual survey carried out by the Macedonian National Extension Agency, gathering farm return data from around 300 farms, in line with the Farm Accountancy Date Network (FADN) principles.

2.3. Climate change scenarios

As indicated in the introduction, climate change is one of the most important considerations for sustainable agriculture, due to its direct impact on agricultural production and consequently indirect effects on the rest of the economy. Increased temperatures will most likely influence the water demand not just in agriculture, but also in other sectors, leading to competition for this natural resource.

Climate change impacts on crop production and water availability in Macedonia have been investigated in several previous studies (Bergant, 2006; MOEPP, 2008; World Bank, 2010; Callaway *et al*., 2011; Sutton *et al*., 2013). Although projections vary, the evidence from all these studies suggests that the stress imposed by climate change will have a negative impact on the yields of most crops in Macedonia. However some agricultural regions and crops are likely to be particularly vulnerable (Table 2).

[Table 2]

As can be seen from Table 2, across the country the most important agricultural crop sub-sectors are categorized as most vulnerable or highly vulnerable.

For the present analysis, the most recent results, from the study conducted by Sutton *et al.* (2013), were applied. In their work, were able to distinguish three climate change scenarios by using 10-year historical data on meteorological and soil characteristics and water resources, in combination with the global circulation model (GCM)[5] for all three AEZ in Macedonia. The driest (high), the wettest (low), and a 'medium' scenario were defined by taking the average Climate Moisture Index (CMI), which is an indicator of the aridity of a region. Generating the decadal, monthly and daily changes in temperature, precipitation and irrigation in combination with the AquaCrop, CropWat and Water Evaluation and Planning System (WEAP)[6] model, those authors were able to simulate the impact of climate change on crop yield variance for the main crops currently grown in Macedonia in irrigated and rainfed environments, considering the water shortage due to climate change.

5. GCM is the most advanced tool currently available for simulating the response of the global climate system to increasing greenhouse gas concentrations (IPCC, 2014).
6. WEAP is a user-friendly software tool that takes an integrated approach to water resources planning (WEAP, 2014).

Overall, Table 3 shows that if no irrigation practices are applied, in almost all scenarios all crops can be expected to have diminished yields. On the other hand, in the situation where the crops are irrigated, only grape and maize growers will be affected negatively by climate change in almost all scenarios in all AEZ. This means that the decadal yield change can be mitigated by irrigation practices overall. The Alpine AEZ was omitted from this analysis due to its marginal spatial coverage in the territory of Macedonia, although Table 3 reveals that climate change can be expected to have positive effects on yield of alfalfa and wheat in that zone. Comparing Tables 2 and 3, it can be seen that in the World Bank (2010) study, maize is also characterized as a vulnerable crop with negative yield change in both AEZ where is grown.

[Table 3]

In order to relate the simulated decadal output changes in Table 3 for each AEZ to the agricultural sub-sector output in the IO table, the following assumptions were made.

From the available data, it is difficult to determine the AEZ from which the output originates. Hence, a simple average of the Mediterranean and Continental yield change was calculated for each respective crop and climate change scenario. This means *e.g.*, that the macroeconomic yield change for irrigated and rainfed maize by the 2040s according to the low impact scenario was 8% and -22%, respectively. Furthermore, it was assumed that the total output is distributed in same proportions of irrigated and rainfed land as shown in Table 4, an assumption justified on the grounds that there is no available information on how much of the output originates from irrigated land and how much from rainfed. In other words, only the output changes, and not the area of cultivated land. Hence, it was assumed for example that yield of 3.02% of cereal production was affected by +8% and that 96.98% of the rainfed output was affected negatively, by -22%. However, the respective changes were adjusted by the proportion contributed by the vulnerable crop to total sector output as listed in the EUROSTAT data on the economic accounts for agriculture. For instance, maize output in 2005 comprised 30.68% of total cereal output. Thus, only 30.68% of the total cereal sector output in 2005 was affected by the demand-driven changes regarding each climate change scenario for maize in the IO table. The same applied for wheat, tomato, apple and alfalfa data.

[Table 4]

Once the changes in the AEZ under the climate change scenarios had been identified, this information was used to derive the impact on agricultural production and the associated water requirement by using the mixed IO model approach. The next section shows how the changes in agriculture according to the climate change scenarios interacted with the rest of the economy.

3. Results

According to the mixed model approach, in the 2005 disaggregated IO table there are 40 sectors (Table 5), of which five outputs were fixed given the vulnerable crops identified in the previous section. The direct and indirect output changes given the supply-driven change and the water requirements for associated sectors under the three climate change scenarios are summarized in Table 5.

In the low case scenario, it is immediately obvious that the sectors cereals (1) and grape production (6) are predicted to decline by about 4% and 1%, respectively, due to the climate change effect. Other sectors such as vegetables (4), fruit (5) and other crops (7) gain a benefit in the low climate change scenario. This is particularly evident for sector (7), mainly dominated by alfalfa, which is predicted to fully utilize the increased cropping period and temperature and the moderate changes in precipitation, leading to an increase in output of around 38%. Alfalfa, the most irrigated crop in this sector, will impose additional stress upon the already intensive water consumption, which will consequently be increased by roughly 16 million m^3 per decade by the 2040s (Hristov *et al.*, 2012). The climate change effects on indirect output (from the rest of the economy) can be disregarded as they represent a marginal percentage change (less than 1%). Therefore, overall there will be net positive effects of low impact climate change, but these will increase water use by 15.58 million m^3 per decade up to the 2040s.

[Table 5]

In the medium and high case scenarios, it is evident that the direct effects of climate change are likely to have a strong negative impact on all sectors. The high impact scenario, with less precipitation and higher evapotranspiration, has a severe impact for the grape (6), cereals (1) and fruit (5) sub-sectors, with a decline in output of around 47%, 20%, and 16%, respectively. The medium case scenario follows the same pattern, with a marked output decline for these sub-sectors

(around 27%, 11%, and 11%, respectively), but the impact is lower due to the moderate increase in temperature and precipitation. These results are to some extent consistent with Table 2, where grape production is categorized as the most vulnerable crop, followed by cereals. Although apple is characterized as a less vulnerable crop, from the results presented in Table 5 it is apparent that fruit production should be categorized as highly vulnerable, given the projected range of negative impact. In contrast, given the projected change in output the vegetable sector should be considered a less vulnerable crop sub-sector. This is because most Macedonian vegetable growers produce their goods as early season crops in controlled conditions, either in greenhouses or plastic tunnels.

Taking into consideration the negative impact of global warming in the medium and high impact scenarios, a marked decline in the overall use of water can be expected in the respective scenarios if the same irrigation practices are maintained. More specifically, for the medium case scenario, the water use is most likely to decline per decade by 21.27 million m^3 by 2040s, whereas for the high case scenario it will decline per decade by 41.17 million m^3 up to 2040s compared with the base case scenario in 2005.

Regarding the magnitude of the indirect decline in output of other sectors, again the change is less than 1% for most sectors, *i.e.*, marginal and hence insignificant. However, there is a decline in output for the sectors refined petroleum (24) and chemical products (25) in response to agricultural output decline, since these products are used as major inputs in agricultural production. When it comes to the water consumption associated with indirect effects, none of the sectors displays significant water consumption that needs to be considered in detail.

4. Discussion and conclusions

This analysis provides indications of the direct impacts of projected climate change on Macedonian agricultural output, and of the indirect effects on the rest of the economy. It shows that climate change will have no major impact on the other sectors in the economy and that the exogenous shocks from climate change will in fact matter the most for the agriculture sector in terms of yield reduction and associated water requirements. It will matter particularly for grape, fruit, cereal and alfalfa production, as they are the most vulnerable crops in the climate change scenarios defined here.

The general findings that agricultural output and water requirements will vary across climate change scenarios may be considered realistic, but certain uncertainties and limitations must be considered before using the results to propose any adaptation measures.

The main limitation in the analysis is that for the climate change impact, the 2005 IO table for the Macedonian economy published by the State Statistical Office (SSO, 2008) was used as the base case scenario. Thus the scenarios do not consider any technological improvements, resulting in uncertainty on how agriculture and the rest of the economy will develop in the long-run. Macedonia has been recognized as a potential candidate member of the European Union (EU), and is thus likely to be affected by the EU Common Agricultural Policy (CAP) and other trade liberalization agreements. In addition, uncertainty about the socio-economic aspects of population growth limits projections of future climate change impacts.

There have been several attempts to forecast and project agricultural output by the 2040s using the EURO method (EUROSTAT, 2008) and the forecasting technique devised by Midmore (1993), but the predictive performance of the model deteriorates rapidly as the time difference between the base and projected year increases. The EURO method is very sensitive at disaggregated level and high growth rates, which characterized some sectors in the Macedonian economy over the period 2005-2010. Consequently, the method overestimates the output and final demand. For example the total output in 2010 in the recent officially published I-O table is 1 146 534 MKD, whereas the corresponding output using the EURO method forecasting technique is 1 554 548 MKD, a discrepancy of around 408 million MKD.

The assumption that irrigation technology and efficiency will remain constant at the 2005 level until the 2040s is another limitation. Irrigation efficiency will most likely decrease due to the increase in temperature and associated increase in evapotranspiration. Deterioration in the functioning of existing irrigation schemes due to the inability of the authorities to cover the costs of historical bad debt and capital depreciation will emphasize the inefficiency even more, unless there is rapid modernization. If we were able to observe agricultural development or structural change over time we could presume expansion of irrigated farmland or modernised irrigation in future scenarios.

Importantly, in defining the climate change scenarios and exogenous shocks, it proved impossible to capture the yield changes for each AEZ separately in an IO framework, as done by Sutton *et al.*

(2013). The uncertainty in the projected climate change scenarios was reduced by considering a wide range of studies elaborating on such matters, which produced the same general conclusions as were used to specify the scenarios. Still, the projected water shortages that Sutton *et al.* (2013) used to define the climate change scenarios do not consider the use of groundwater resources, but are limited to the use of surface water.

The direct effect of heat stress upon livestock was not included, despite the fact that in all studies cited on climate change and Macedonia, the livestock sector is categorized as vulnerable, but without any specific quantitative impacts. The increase in temperature and the associated risk of diseases and increased mortality are especially important for the modern highly productive livestock breeds. However, with the exogenous shock on forage crop production it proved possible to capture the indirect effect on cattle production, which turned out to be very marginal.

The analytical method used to investigate climate change from an economic perspective may be an additional cause of uncertainty in the projections. In their study, Iglesias *et al.* (2012) used a Computable General Equilibrium (CGE) model. However, in order to implement such a model, data on prices, input substitution and elasticities as key instruments in the adjustment of the economy to climate change shock are needed, but are not available for the Macedonian economy. Thus, the choice of IO model was based on its ability to explain the relationships between climate-sensitive sectors in a disaggregated environment (Rose *et al,.* 2000). It is noteworthy that it provided informative preliminary results on climate change impact which give a possible indication of how the economy may develop in the future and which adaptation measures to prioritize. A sensitivity analysis is probably necessary, however, given the assumptions and uncertainties created while constructing the climate change scenarios. It is probably also necessary to analyze demand-driven change with respect to capital investment in the restoration and development of irrigation infrastructure that provides a sufficient supply of water to mitigate the climate change impact.

In conclusion, several major points emerged from this work. First, it is evident that the exogenously defined direct climate change effect can be expected to have varying impacts on agricultural crop output, but insignificant effects upon the rest of the economy. Second, with the differing direct effects of climate change across different future scenarios, the physical impact (*i.e.*, water consumption) will also vary, with an increase in the low impact scenario and a decrease in the medium and high scenarios. Overall, the results obtained in this study indicate that special attention

should be paid to agricultural production sectors posing the greatest potential opportunities and threats.

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References

Aladzajkov, L. (1974). *Collection and study of vegetables and small fruits throughout Macedonia*. Final Report Project No. E30-SR-33. Institute of Agriculture, Skopje, Macedonia.

Bergant, K. (2006). *Climate Change Scenarios for Macedonia – Summary*. University of Nova Gorica. Slovenia.

Callaway, J.M., Markovska, N., Cukaliev, O., Causevski, A., Gjoshevski, D., Taseska, V. and Nikolova, S. (2011). *Assessing the Economic Impact of Climate Change : National Case studies.* UNDP. Skopje, Macedonia.

Ciscar, J.C., Iglesias, A., Perry, M. and van Regemorter, D. (2012). *Agriculture, climate change and the global economy*. Draft paper. European Commission.

Cornish, G., Bosworth, B., Perry, C. and Burkey, J. (2004). Water charging in irrigated agriculture: An analysis of international experience. FAO Water Reports 28. Food and Agricultural Organization of the United Nations. Rome.

EUROSTAT (2008). *Eurostat Manual of Supply, Use and Input-Output Tables*. Office for Official Publications of the European Communities, Luxembourg.

Galev, T. and Arsovski, B. (1990). *Organization of Agricultural Enterprises and Organization of Livestock production*. University "Ss. Cyril and Methodius" - Skopje. Skopje, Macedonia.

Gorton, M., Sauer, J., Peshevski, M., Bosev, D., Shekerinov, D. and Quarrie, S. (2009). Water Communities in the Republic of Macedonia: an empirical analysis of membership satisfaction and payment behaviour. *World Development*, 37: 12, 1951-1963.

Hoekstra, A.Y. and Hung, P.Q. (2002). Virtual water trade: A quantification of virtual water flows between nations in relation to international crop trade. *Value of Water Research Report Series No.11*. UNESCO-IHE.

Hristov, J. Martinovska-Stojceska, A. and Surry, Y. (2012). *Input-Output analysis for water consumption in Macedonia.* Working paper presented at the European Summer School in Resource and Environmental Economics: Management of International Water. 1–7 July 2012. Venice, Italy.

Iglesias, A. Garrote, L., Quiroga, S. and Moneo, M. (2012). A regional comparison of the effects of climate change on agricultural crops in Europe. *Climatic Change* 112, 29-46.

Iljovski, I. (1990). *Irrigation: Compendium for the students at the Faculty for Agriculture in Skopje*. Faculty of Agriculture, Skopje, Macedonia.

IPCC – Intergovernmental Panel on Climate Change, http://www.ipcc-data.org/

1. *What is GCM?*, 20-05-2014, http://www.ipcc-data.org/guidelines/pages/gcm_guide.html

Leontief, W. (1936). Quantitative input-output relations in the economic system of the United States. *Review of Economics and Statistics*, 18, 105–125.

Leontief, W. (1970). Environmental repercussions and the economic structure: An input-output approach. *Review of Economics and Statistics*, 52(3), 262-271.

Lindberg, G. and Hansson, H. (2009). Economic impacts of agriculture in Sweden: A disaggregated input–output approach. *Food Economics–Acta Agriculturae Scandinavica* C. 6 (2), 119-133.

MAFWE - Ministry of Agriculture. Forestry and Water Economy (2008-2011). *Agricultural Annual Report (Various issues, 2009-2012)*. Skopje, Macedonia.

Martinovska-Stojcheska, A., Georgiev, N. and Erjavec, E. (2008). Farm income analysis of agricultural holdings in Macedonia using FADN methodology. *Acta Agriculturae Slovenica* 92(1): 41-51.

Martinovska-Stojcheska, A., Dimitrievski, D., Surry, Y., Sergo, L. and Andersson, H. (2011). Economic and technical analysis of Macedonian farms based on the farm accountancy data: 2005-2009 period. UniCoop publication, Faculty of Agricultural Sciences and Food – Skopje and Swedish University of Agricultural Sciences – Uppsala.

Midmore, P. (1993). Input-output forecasting of regional agricultural policy impacts. *Journal of Agricultural Economics* 44, 284-300.

Miller, R. E. and Blair, P. D. (2009). *Input-output analysis. Foundations and extensions.* Cambridge: Cambridge University Press. Second edition.

MOEPP - Ministry of Environment and Physical Planning (2006). *Second National Report under the United Nations Climate Change Kyoto Protocol: Assessment of vulnerability and adaptation of the water resource sector.* Skopje, Macedonia.

MOEPP (2008). *Second National Communication on Climate Change.* Skopje, Macedonia.

MOEPP (2010) *Water Strategy of the Republic of Macedonia:* Draft final version. Skopje, Macedonia.

Roberts, D. (1994). A modified Leontief model for analysing the impact of milk quotas on the wider economy. *Journal of Agricultural Economics* 45(1), 90-101.

Rose, A., Cao, Y. and Oladosu, G. (2000). Simulating the economic impacts of climate change in the Mid-Atlantic Region. *Climate Research* 14, 175-183.

Steinback, S. (2004). Using ready-made regional input-output models to estimate backward linkage effects of exogenous output shocks. *Review of Regional Studies* 34, 57-71.

SSO – State Statistical Office (2007a). Agricultural Census, Book III. Skopje, Macedonia.

SSO (2007b) State Statistical Yearbook 2006, Skopje.

SSO (2008). *Symmetric Input-Output Tables for the Republic of Macedonia, 2005.* Statistical Review: National Economy and Finances. Skopje, Macedonia.

SSO (2012). *Labor Force Survey 2011.* Skopje, Macedonia.

Sutton, W.R., Srivastava, J.P., Neumann. J.E., Strzępek, K.M. and Boehlert, B.B. (2013). *Reducing the vulnerability of the Former Yugoslav Republic of Macedonia's Agricultural Systems to Climate Change.* Washington. DC: World Bank.

Tanjuakio, R., Hastings, S.E. and Tytus, P.J. (1996). The Economic contribution of agriculture in Delaware. *Agricultural and Resource Economics Review* 25, 46–53.

Velazquez, E. (2006). An input–output model of water consumption: Analyzing intersectoral water relationships in Andalusia. *Ecological Economics* (56), 226- 240.

WEAP – Water Evaluation and Planning, http://www.weap21.org/

1. *Welcome to WEAP*, 20-05-2014, http://www.weap21.org/index.asp?NewLang=EN

World Bank (2010). *The Former Yugoslav Republic of Macedonia; Agriculture and Climate Change Country Note.*

World Bank. http://www.worldbank.org/

1. *Country Profile:* Republic of Macedonia, 07-03-2014, http://siteresources.worldbank.org/CMUDLP/Resources/Macedonia_report.pdf

Tables

Table 1. *Area (ha) of irrigated crop land in Macedonia, according to two recent reports*

	2008 Annual Agricultural Report					Agricultural Census
	2004	2005	2006	2007	2008	2007
Cereals	7 501	6 170	6 780	7 743	6 919	24 360
Industrial crops	2 129	2 131	1 550	1 300	1 012	4 533
Vegetables	2 283	2 801	1 956	1 468	1 920	15 499
Forage crops	3 159	2 468	2 943	2 807	2 907	4 388
Fruit	1 785	1 574	1 194	1 371	1 501	5 908
Grapes	5 988	5 045	3 592	7 155	6 211	8 467
Other	315	551	319	317	1 100	1 635
Pastures and meadows						4 277
Total irrigated land	23 160	20 740	18 334	22 161	21 570	69 070

Source: Adapted from MAFWE (2009) and SSO (2007a, Book III, p.101).

Table 2. *Vulnerability of agricultural regions and crops in Macedonia to climate change by 2100*

Vulnerability	Agro-ecological zone and location	Crop
Most vulnerable	Mediterranean Zone: Povardarie	Grape
Highly vulnerable	Mediterranean Zone: Strumica	Tomato
	Mediterranean Zone – Gevgelija: southern Vardar valley	Tomato
	Mediterranean Zone – Skopje: Kumanovo valley	Winter wheat
	Mediterranean Zone – Ovce Pole	Winter wheat
Less vulnerable	Continental Zone: Pelagonija valley	Alfalfa
	Continental Zone: Prespa/Ohrid region	Apple

Source: World Bank (2010).

Table 3. *Decadal range of crop yield change relative to the current situation (% by 2040s) across the three climate scenarios high, medium and low*

		Mediterranean			Continental			Alpine		
	Crop	Low	Medium	High	Low	Medium	High	Low	Medium	High
Irrigated	Alfalfa	33	5	4	42	28	21	92	71	68
	Apples	10	9	9	15	13	11	15	15	14
	Grapes	-3	-14	-35	12	-23	-39	N/A	N/A	N/A
	Maize	-9	0	-11	25	27	19	N/A	N/A	N/A
	Vegetables	19	11	3	8	10	3	N/A	N/A	N/A
	Wheat	15	16	13	28	30	25	113	100	76
Rainfed	Alfalfa	45	-10	-17	42	2	-10	56	42	43
	Apples	-7	-45	-60	6	-41	-63	-4	6	13
	Grapes	-12	-25	-47	8	-32	-53	N/A	N/A	N/A
	Maize	-52	-62	-76	8	-54	-77	N/A	N/A	N/A
	Vegetables	10	-11	-21	-8	-9	-28	N/A	N/A	N/A
	Wheat	-1	6	-3	15	25	13	105	99	70

Source: Adapted from Sutton et al. (2013).

Note: N/A indicates that the crop is not grown in the AEZ in question.

Table 4. *Comparison of irrigated and rainfed agricultural cropping area in Macedonia according to two official sources*

Year	2005			
	Area (ha)		Proportion (%)	
Crop	irrigated	rainfed	irrigated	rainfed
Cereals	6 170	197 830	3.02	96.98
Industrial crops	2 131	16 357	11.53	88.47
Vegetables	2 801	49 401	5.37	94.71
Forage crops	2 468	31 532	7.26	92.74
Fruit	1 574	11 426	12.11	87.89
Grape	5 045	19 999	20.14	79.86
Other	551	198 164	0.28	99.72
Total	20 740	525 260		

Source: Adapted from MAFWE (2009) and SSO (2007a, Book III).

Table 5. *Changes in output and water use of agriculture and other sectors due to climate change scenarios*

		2005		Output change (%)			Change in water use (mill m^3)		
	Sector	Output (mill. MKD)	Water use (mill. m^3)	Low	Medium	High	Low	Medium	High
1	**Cereals**	6 383	26.11	**-3.41**	**-10.65**	**-20.49**	**-1.25**	**-3.90**	**-7.50**
2	Rice	488	14.07	0.01	-0.11	-0.21	0.03	0.00	-0.06
3	Raw tobacco	4 159	11.27	0.00	0.00	0.00	0.00	0.00	0.00
4	**Vegetables**	17 016	41.98	**0.25**	**-1.34**	**-3.47**	**0.08**	**-0.40**	**-1.04**
5	**Fruits**	3 728	23.65	**0.33**	**-11.28**	**-16.34**	**0.05**	**-1.86**	**-2.70**
6	**Grapes and wine**	5 506	49.82	**-0.69**	**-26.49**	**-47.38**	**-0.36**	**-13.72**	**-24.55**
7	**Other crops**	3 318	43.73	**38.12**	**-2.22**	**-10.28**	**16.96**	**-0.98**	**-4.57**
8	Cattle	7 554	25.59	0.01	-0.05	-0.09	0.00	-0.01	-0.02
9	Pigs	2 697	5.02	0.00	-0.06	-0.10	0.00	0.00	0.00
10	Sheep/lamb	2 005	11.04	0.00	-0.03	-0.05	0.00	0.00	-0.01
11	Other livestock	2 811	2.81	0.00	-0.04	-0.08	0.00	0.00	0.00
12	Forestry	1 492	0.00	0.00	-0.01	-0.01	0.00	0.00	0.00
13	Fishing activities	72	0.00	0.03	-0.04	-0.08	0.00	0.00	0.00
14	Mining and quarrying	5 807	161.32	0.02	-0.07	-0.14	0.04	-0.11	-0.22
15	Other mining	3 639	26.43	0.01	-0.08	-0.15	0.00	-0.02	-0.04
16	Food and beverages	30 951	103.37	0.01	-0.14	-0.26	0.01	-0.14	-0.26
17	Tobacco products	8 975	0.40	0.00	0.00	0.00	0.00	0.00	0.00
18	Textiles	2 987	0.45	0.00	0.00	0.00	0.00	0.00	0.00
19	Wearing apparel; furs	27 025	0.97	0.00	0.00	0.00	0.00	0.00	0.00
20	Leather products	2 877	0.04	0.00	0.00	0.00	0.00	0.00	0.00
21	Wood products	1 674	2.20	0.01	-0.03	-0.05	0.00	0.00	0.00
22	Pulp. paper products	5 155	0.08	0.05	-0.08	-0.16	0.00	0.00	0.00
23	Printed matter	1 058	0.29	0.02	-0.08	-0.14	0.00	0.00	0.00
24	Refined petroleum	22 243	0.28	0.40	-1.16	-2.18	0.00	0.00	-0.01
25	Chemicals	5 786	4.71	0.03	-0.95	-1.78	0.00	-0.04	-0.08
26	Rubber and plastic	4 308	0.07	0.04	-0.38	-0.66	0.00	0.00	0.00
27	Other mineral prod.	6 574	1.46	0.02	-0.06	-0.12	0.00	0.00	0.00
28	Basic metals	30 138	68.13	0.00	0.00	-0.01	0.00	0.00	0.00
29	Fabricated metal	4 231	0.09	0.03	-0.04	-0.08	0.00	0.00	0.00
30	Machinery	2 117	4.52	0.15	-0.58	-1.06	0.01	-0.03	-0.05
31	Electrical machinery	5 157	42.81	0.02	-0.04	-0.07	0.01	-0.02	-0.03

Table 5 continues

32	Medical instruments	400	0.01	0.00	0.00	-0.01	0.00	0.00	0.00
33	Motor vehicles	1 815	0.17	0.01	-0.02	-0.04	0.00	0.00	0.00
34	Other transport	659	0.13	0.00	0.00	0.00	0.00	0.00	0.00
35	Furniture	1 782	0.31	0.03	-0.04	-0.08	0.00	0.00	0.00
36	Secondary materials	684	0.002	0.00	-0.01	-0.02	0.00	0.00	0.00
37	Electrical energy	14 537	1.00	0.06	-0.16	-0.35	0.00	0.00	0.00
38	Collected water	2 649	0.00	0.01	-0.03	-0.06	0.00	0.00	0.00
39	Construction work	42 406	1.00	0.00	-0.01	-0.03	0.00	0.00	0.00
40	Other services	253 812	8.40	0.05	-0.08	-0.15	0.00	-0.01	-0.01
	Total		683.78				15.58	-21.27	-41.17

Note: Mill. = million;

61.5 MKD (Macedonian Denar) = 1 €; National Bank of Republic of Macedonia.

Bold indicates the five fixed sectors in the mixed model approach or the direct supply-driven shock for the vulnerable crops.

The absolute variation in water use was obtained using the derived water coefficients for each sector (Velazquez, 2006) which were assumed to be the same over the years, *i.e.*, **water use/output = direct water coefficient.** Therefore, by knowing the change in output, the absolute change in water use is: *i.e.,* **direct water coefficient * output variation = water use variation.**

Figures

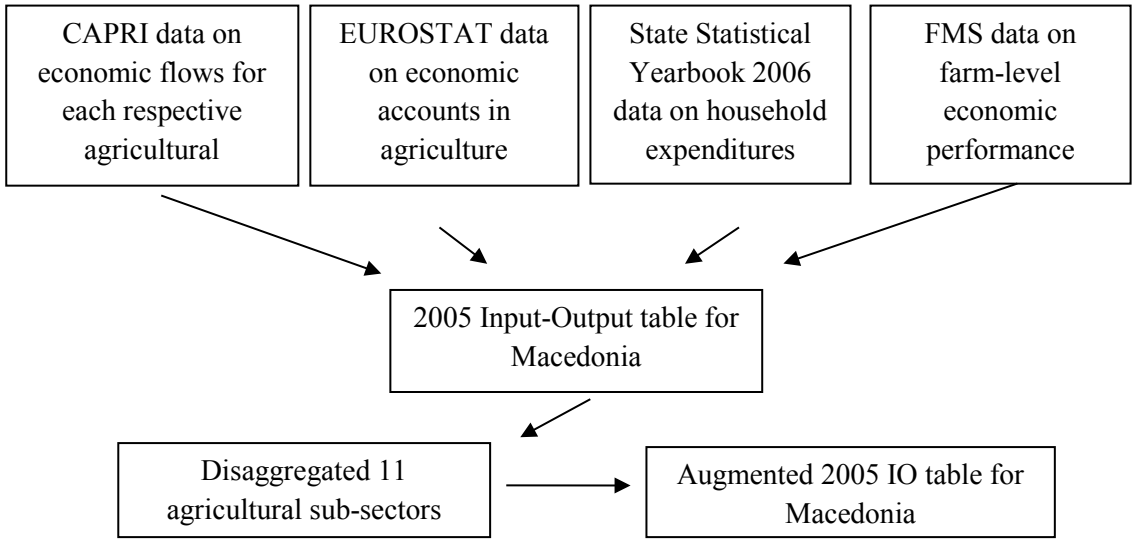
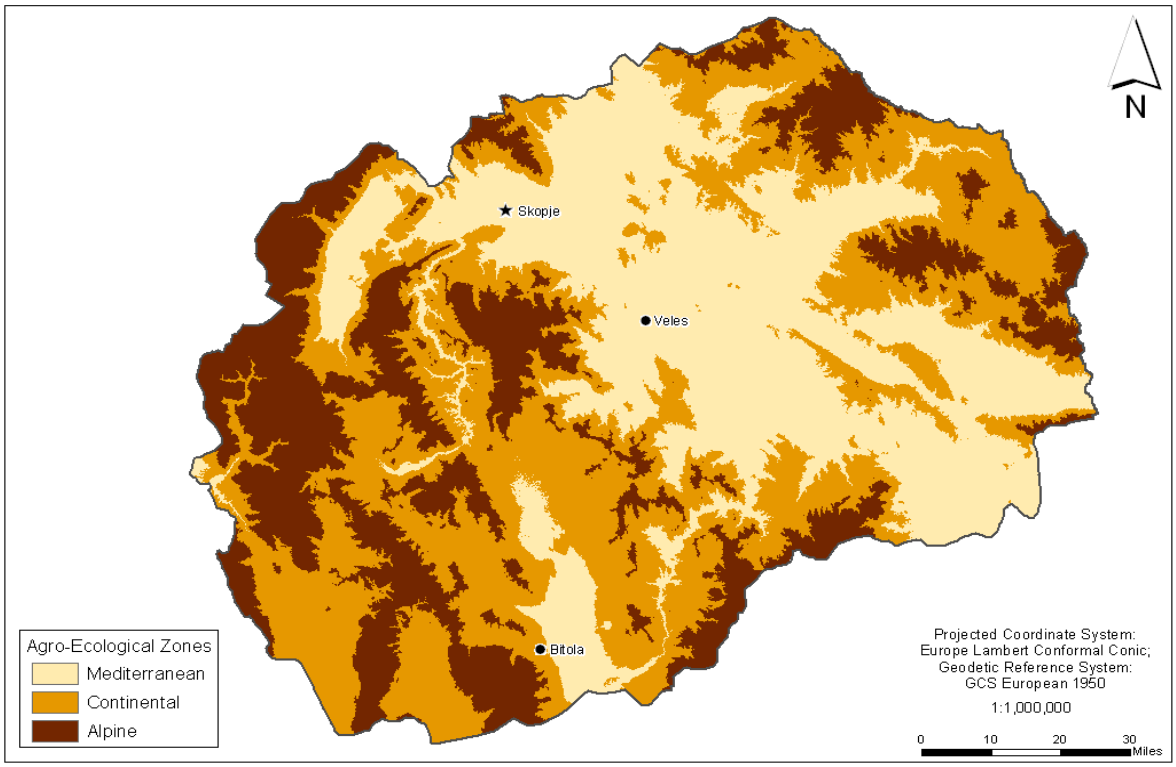
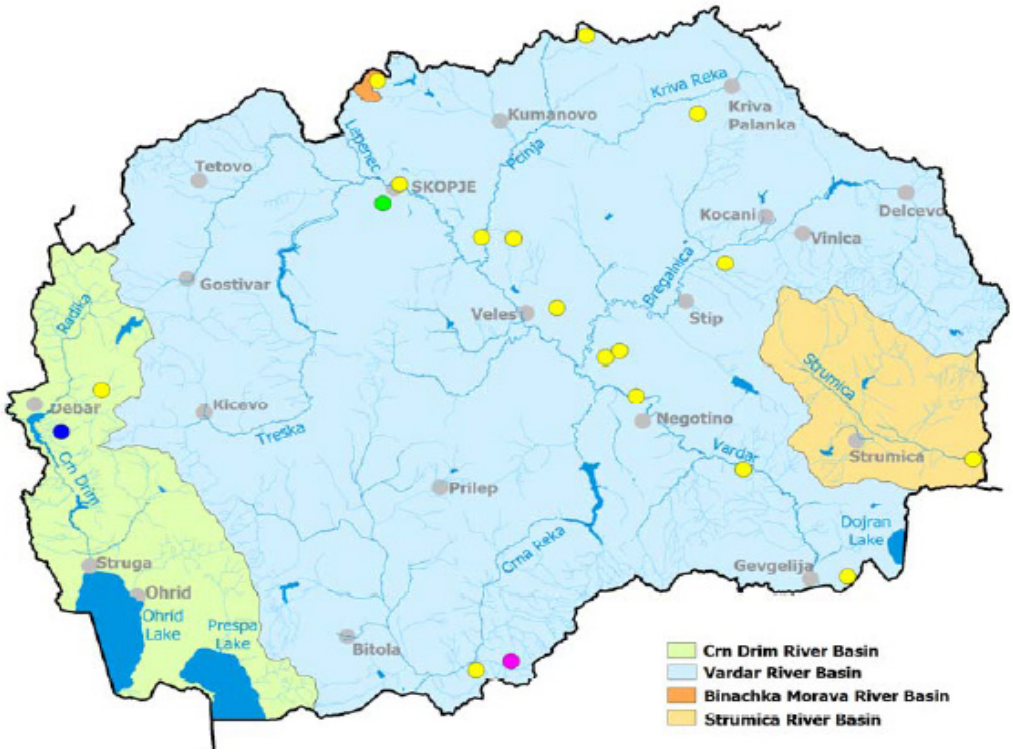


Figure 1. *Steps involved in disaggregating the agriculture sector of the input-output table for Macedonia*

Appendix 1. *Agro-ecological zones (AEZ; upper diagram) and river basin zones (lower diagram) in the Republic of Macedonia*



Source: Sutton *et al.* (2013).



Source: MOEPP (2010).