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ORIGINAL ARTICLE

Can the Middle East-North Africa region mitigate the rise of its food import dependency under climate change?

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Abstract

The dependence on imports of the Middle East and North Africa (MENA) region for its food needs has increased steadily since the early 1960s, from 10% to about 40%. This import dependence could continue to rise in coming decades due to the projected MENA population growth and the expected negative impacts of climate change on the region's natural resources and agricultural performances. To what extent the food import dependency of the MENA region will continue to increase up to 2050 and how the region could mitigate its rising reliance on food imports is both a key question for the region itself and a crucial geopolitical issue for the world as a whole. In this paper, we use a biomass balance model to assess the level of the food import dependency of the MENA region in 2050 resulting from six scenarios. We show that under current trends and severe impacts of climate change the food import dependency of the MENA would continue to rise and reach 50% in 2050. Maghreb would be particularly affected becoming dependent on imports for almost 70% of its food needs. Adopting a Mediterranean diet, reaching faster productivity growth in agriculture or reducing waste and loss along the food chain would contribute to decelerate the rise of the MENA's food import dependency. However, only the combination of these three options could significantly offset the increased import dependency in the most affected sub-regions: Maghreb, the Middle and the Near East. In all scenarios, Turkey strengthens its position as a net exporter of agricultural products.

Keywords Food system · Agricultural production · Food diet · MENA · Scenarios · Biomass balance model

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Introduction

The Middle East and North Africa (MENA) region[1] is characterized by both a high percentage of arid and semi-arid lands with low agricultural productivity (Nin Pratt et al. 2018) and a rapid demographic expansion with a population that has increased from about 140 million in the early 1960s to over 500 million in 2020 (UN 2019). As a result of both factors, the agricultural import dependency of the MENA region has increased dramatically since the 1960s: the MENA import dependency rate (measured as the percentage of kilocalories consumed supplied by imports) rose from 10 in 1961 to 40% in 2011 (Marty et al. 2018).

The region's population growth combined with the evolution of eating habits that economic development, rapid urbanization and food price policies involve have led to an increased demand for food and other agricultural products. In the MENA region, these dietary changes include a steady nutritional transition while certain features of the previous Mediterranean diet are maintained. On the one hand, according to FAO data, daily caloric availability has increased sharply, reaching 3200 to 3700 kcal/cap/day on average, with a significant increase in the proportion of vegetable oils and sugary foods in the diet (Marty et al. 2018). On the other hand, changes in dietary habits differ from the "Western" model in the extremely low amount of animal foods consumed (which has levelled out at 10% of caloric intake) (Marty et al. 2018). These trends have led to a sixfold increase in regional demand for agricultural products over a period of 50 years.

Although crop production in the region has increased dramatically (fourfold in 50 years), it has been unable to keep pace with these changing demographics and food requirements. For cereal crops in particular, significant and lasting yield gains have been achieved only in Turkey and Egypt. The Middle East, the Near East and the Maghreb remain well behind in terms of cereal yields and output, with the Maghreb and the Near East also experiencing high inter-annual variability in terms of yields. Furthermore, the shifts in animal production (especially the emergence of intensive poultry operations) have led to a reduction in grassland and a weakening of the region's pastoral tradition, in addition to the increase in demand for feed crops, like maize and soybeans (Marty et al. 2018).

Consequently, the region's food import dependency has increased significantly and the MENA region has become one of the most central actors of international agricultural and food trade (Nigatu and Motamed 2015), even if sub-regions face different situations. Over the last 50 years, the Maghreb and the Middle East saw their levels of import dependency respectively increase from 10 to 54% and from 15 to 50%. In the Near East, where import dependency already stood at 40% at the beginning of the period, a similar 50% level was reached by 2011. Egypt shows lower levels of agricultural import dependence, but nevertheless moved from 10 to 30% over the same time period. Turkey is the only exception within the region, with a historically low agricultural import dependency that has reached 10% only in the past few years.

In addition, the MENA region is considered as a climatic hotspot where the effects of a rise in global temperatures could be amplified: regional increase in temperature are likely to be higher than global averages, more intense and more frequent extreme heat events, increased aridity due to higher evaporation, increased scarcity of rainfall, increased drought risk and the multiplication of periods of drought (Hare et al. 2011; Waha et al. 2017; IPCC 2019). Potential consequences of these evolutions on the adaptation conditions of local agriculture are many: water supply, salinization, soil erosion, lower yields, etc. (Iglesias et al. 2011; Bucchignani et al. 2018; IPCC 2019; Namdar et al. 2021). Many of these issues already exist in the region, but accelerated climate change will likely exacerbate them. These additional constraints could make the gap even larger between demand for agri-food goods and regional supply, by limiting the yield increase and by reducing already limited cultivable land areas.

Hence, due to the limitation of the domestic production potential, the food import dependency of the MENA region could continue to increase during the next decades (Jobbins and Henley 2015) and become a key challenge for the MENA region itself, but also for the world as a whole. As the MENA region has become a big player on world food markets, an increase in its import volumes is likely to contribute to upward pressures on food prices, and thus a potential deterioration in food access for the poorest in the MENA and in the rest of the world as well.

For the MENA countries themselves, relying increasingly on agricultural imports has ambiguous consequences. On the one hand, in arid and semi-arid countries, importing water-intensive foods may be a consistent way to make food more affordable to domestic consumers. Indeed, in countries where improving agricultural productivity has a significant

[1] In this study, the MENA region involves the following sub-regions and countries: Egypt; Maghreb (Algeria, Lybia, Mauritania, Morocco, Western Sahara, Tunisia); Middle East (Bahrein, Iran, Irak, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates, Yemen); Near East (Israel, Jordan, Lebanon, West Bank and Gaza, Syria); Turkey. Table SM1 in Supplementary Material reports for each country, sub-regions and the MENA region, population, several macroeconomic indicators (GDP, GDP per capita, current account balance) and values of trade in agricultural products, all computed as an average over the years 2018–2020.

opportunity cost in terms of development of other sectors, investing in domestic agriculture may delay economic diversification and growth and in turn slow down the rise of income and purchasing power of food consumers (e.g. Allan 2001). In this sense, increasing agricultural import dependency would contribute to MENA countries' food security. On the other hand, by increasing their agricultural import dependency, MENA countries exacerbate their exposure to price shocks in global food markets, be these shocks provoked by a global economic and financial crisis (like in 2008–2011), or a disruption of supply chains (as observed during the COVID 19 pandemics) or a political or geopolitical crisis affecting any part of the world (as the current conflict between Russia and Ukraine perfectly shows). In this sense, increasing agricultural import dependency would rather weaken MENA countries' food security (Sadler and Magnan 2011; Nigatu and Motamed 2015; Jobbins and Henley 2015; Nin Pratt et al. 2018; OECD/FAO 2018; Zolfaghari and Jariani 2021).

Obviously, the risks incurred by countries exhibiting a high rate of import dependency depend on their capacity to pay their agricultural imports, the sensitivity of their consumers to food price shocks and their capacity to mitigate the effects of price shocks on domestic consumers. Table SI1 (provided in Supporting information SI Macroeconomic indicators), reports for each MENA region and in average over 2018–2020, some macroeconomic indicators, including the GDP per capita, the current account balance and the agricultural trade balance. Numerous countries appear as very fragile as regards price fluctuations on world agricultural markets, with agricultural net imports accounting for more than 5% of their GDP, negative current account balance and low GDP per capita making their consumers very sensitive to food price shocks (e.g. Syria, West Bank and Gaza, Yemen and Algeria, Mauritania, Jordan and Lebanon). Only a few countries, either large oil exporters and/or more developed with higher GDP per capita, seem to be able to cope with price shocks on world agricultural markets (Kuwait, Qatar, Saudi Arabia, Israel, Turkey).

Therefore, most MENA countries are highly exposed to international markets fluctuations. Such fluctuations can quickly jeopardize their capacity to pay for their imports and supply their food system, deteriorate their budget balance and increase State debts. In such situations, recurrent food crises are likely and may induce social instability, riots, internal and international migration, and contribute to weaken political powers in place (Lagi et al. 2011; Natalini et al. 2019). In an already unstable region marked by a set of long and complex conflicts, like the MENA region is, the perspective of increased food import dependency is thus likely to be a crucial geopolitical issue for the MENA itself but also for the world as a whole.

In this paper, we examine how the dependence on agricultural imports of the MENA region and its different sub-regions could evolve by 2050. First, we assume that past trends continue in the MENA region. Second, we envisage alternative scenarios involving three levers by which the different MENA sub-regions could mitigate the increase of their dependence on agricultural imports. We use a biomass balance model (GlobAgri-MENA)[2] to assess the level of the food import dependency of the MENA region and its five sub-regions (Egypt, Maghreb, Middle East, Near East and Turkey) in 2050 resulting from six scenarios. The first two scenarios are baseline scenarios to 2050: continuation of current trends (Ref) and continuation of current trends with increased climate change impacts (Ref with CC). Three additional scenarios consider each a possible option for mitigating the MENA's food import dependency: change in diet (Mediterranean diet, combining compliance with nutritional recommendations regarding caloric content and return to the traditional Mediterranean diet observed in the region in the 1960s regarding the structure of the diet), increase in crop yields and livestock productivity (Technical progress) and reduction of waste and loss all along the food chain (Reduced waste and loss). The last scenario combines the three levers (Three levers).

Our study follows up on several foresight studies on the Mediterranean region. The ARP PARME study (Hubert et al. 2011) and the Agropolis International study (Agropolis International 2011) focused on the ongoing dynamics and future tendencies in the region concerning population, economic activities and natural resources. Both studies tackled these issues for 2030. Other studies focused on the effects of climate change on natural key resources in southern and eastern Mediterranean (Ayadi and Sessa 2013), on agricultural productivity (Belghazi 2013; Nin Pratt et al. 2018) or on some food security issues (Jobbins and Henley 2015; Tull 2020; Zolfaghari and Jariani 2021). Unlike some of these studies, the present one concentrates on the countries of Maghreb, Machrek, the Arabic Peninsula and Turkey, grouped in five sub-regions. Moreover, although agri-food systems are always part of a broader context, our study focuses on the regional agri-food systems and the capacity of their components to contribute to—or, on the contrary, help mitigate—a continued increase in the region's agricultural import dependency. Furthermore, while the previously cited studies focus on qualitative dynamics and their potential for change via the construction of scenarios, we integrate such qualitative dynamics in a modelling tool, allowing for a

[2] Also named GlobAgri-Pluriagri in Le Mouël and Schmitt (2018).

quantitative assessment of each of our scenarios. Lastly, our study's time horizon reaches out to 2050.

Materials and methods

The GlobAgri-MENA model

GlobAgri is an information system and quantitative modelling tool developed by CIRAD and INRAE to analyse agricultural resource use and availability at both global and regional levels (Le Mouël et al. 2018; Mora et al. 2020). For this study, we used a version of GlobAgri called GlobAgri-MENA (Le Mouël and Schmitt 2018). Using mostly the Commodity Balances from the FAOStat database and a few sources of complementary data for the past and present situation, GlobAgri-MENA divides the MENA region into five sub-regions while the rest of the world is divided into 12 regions. For each of the 17 regions/sub-regions and each year, the model establishes a balance for 28 vegetal products and 8 animal products in which domestic production plus net imports (imports minus exports) equals the sum of all alternative uses of the product: food, feed, other uses, wastes (mainly associated with the distribution phase) and stock variations.

Furthermore, feed use of vegetal products is a linear combination of outputs of animal products (through feed to output ratios). Imports of each product depend linearly on the total domestic use of the product (through import dependency coefficients). While exports are a linear function of the world market size, i.e. the sum of all regions' imports (through export market shares).

To simulate a scenario, food consumption levels (or other exogenous variables such as other uses or wastes for example) are set a priori by the modeller, along with production-side technical variables such as crop yields and livestock productivity, also exogenous in the model. The levels of imports, exports and domestic production will then adjust to achieve equilibrium between resource availability and resource use. To do so, and to preserve the global coherence in the model, two constraints are introduced: the first one ensures that at the world level, for each product the sum of all imports equals the sum of all exports; the second one imposes a maximum cultivable land area for each region that cannot be surpassed.

In regions where the limit on cultivable land area is reached, equilibrium must be achieved by reducing exports (via a decrease in the region's export shares) and/or increasing imports (via an increase in the coefficients of import dependence). More specifically, for a region exceeding its maximum cultivable land area, export shares are decreased equi-proportionnally for all products. If even with zero exports, the region still needs more cultivated area than its maximum cultivable area; then, the region starts increasing its imports (through increases in import dependence coefficients). In other words, the region increases the share of its food needs, which is covered by imports in order to reduce the required rise in domestic production and save some cultivated area. As initial import dependence coefficients of regions vary widely across products, we defined intervals of initial levels upon which the coefficients are increased evenly, allowing for differentiating the level of increase by band. In the case of the MENA region, the model does not adjust quantities exported via a reduction in the percentage of the export market, these being supposedly stable given the specificity of the production types involved (mainly fruits and vegetables as cash crops). The adjustment in the MENA region is made only via an increase in imports (i.e. the coefficients of import dependence) (Le Mouël and Schmitt 2018).

If the limit on cultivable land area is not reached, the region will conserve its initial shares of the global export markets and its initial coefficients of import dependence, with domestic production being adjusted as necessary to achieve equilibrium.[3] The model thus implicitly supposes that trade between a given region and the rest of the world is not always readily adjustable, but rather presents a certain degree of rigidity. This inflexibility can result in situations in which the freeing up of cultivable land may coincide with the maintenance of a certain level of imports, rather than a decrease in imports, which would result from the use of all the available cultivable land. This is the particular situation of Turkey in every scenario and that is why we have made some ex post calculations for all results under the assumption that in each scenario Turkey exploits all its cultivable land (i.e. reaches its cultivable land area constraint) allowing for an increase in production and exports (Le Mouël and Schmitt 2018).

Scenarios

Six scenarios were simulated with GlobAgri-MENA (Table 1). The baseline scenario (Ref) is the continuation of existing trends in the MENA region between 2008 (average 2007–2009) and 2050. An alternative baseline scenario (Ref with CC) was considered. It is based on Ref but involves increased climate change impacts. More specifically, it is based on the most extreme case projected by the IPCC, corresponding to a radiative forcing of 8.5 W/m^2 (RCP-8.5). Increased climate change impacts in the region will negatively affect crop yields and cultivable land area for rainfed systems. Potential impacts on irrigated agriculture and on livestock productivity are not taken into account.

[3] Note that some slight adjustments in exports may nevertheless take place for these regions, particularly in order to meet import needs of regions constrained by their cultivable land areas.

Table 1 Overall description of simulated scenarios (for more details see SI Materials and methods)

Scenario	Demography	Food	Crop yields	Livestock productivity	Cultivable land
Reference scenario (Ref)	Median forecast from UN (2013)	Projection of historical trends (past 20 years)	Projection of historical trends (past 20 years)	Reduction of pastoral systems' shares, projection of input/output coefficients of mixed and pastoral systems as of Bouwman et al. (2005)	Observed 2008 (avg 2007–2009) cultivated area
Reference scenario with increased CC impacts (Ref with CC)	As in Ref	As in Ref	Rainfed crop yields vary as of Müller and Robertson (2014) for RCP 8.5	As in Ref	Rainfed land is reduced as of Zabel et al. (2014) for RCP 8.5
Mediterranean diet	As in Ref with CC	Food availability per capita fixed at 2800 kcal for all sub-regions; each sub-region goes back to its average food structure in 1961–1963	As in Ref with CC	As in Ref with CC	As in Ref with CC
Technical progress	As in Ref with CC	As in Ref with CC	Increase of all crop yields by 20% (capped at the potential irrigated crop yield level or at the Ref yield level if potential yield < Ref yield)	Increased livestock efficiency (decrease of all input/output coefficients by 20%)	As in Ref with CC
Reduced waste and loss	As in Ref with CC	Reduction of per capita food availability by half of waste percentages (distribution and consumption level) indicated by FAO (2011)	Increase in yields on the basis of half of the loss percentages (post-harvest) indicated by FAO (2011) (capped at the potential irrigated crop yield level or at the Ref yield level if potential yield < Ref yield)	As in Ref with CC	As in Ref with CC
Three Levers	As in Ref with CC	As in Mediterranean diet + as in Reduced waste and loss	As in Technical progress + as in Reduced waste and loss	As in Technical progress	As in Ref with CC

Three alternative scenarios applied to the Ref with CC scenario were tested to analyse how different mechanisms supported by specific policies could help the region to slow its increasing food import dependency. One of them considers more favourable demand side evolutions, which would induce lower domestic food demand: the Mediterranean diet scenario proposes to bring the caloric content of the diet closer to nutritional recommendations, and the structure of the diet back to the traditional Mediterranean diet observed in the 1960s in the region. Another one includes supply-side improvements, which would allow higher domestic food supply: the Technical progress scenario considers a 20% additional increase in crop yields and livestock productivity in 2050 relative to the Ref with CC scenario. The last one addresses the problem of waste and loss of primary agricultural products at each stage of the food chain: the Reduced waste and loss scenario consider a reduction by half of both the waste on the distribution and consumption side, and the loss on the production and storage side, as calculated for the MENA region by FAO (2011). Finally, the scenario Three levers combines the three above-described scenarios. All scenarios and underlying quantitative assumptions are described in SI Materials and methods.

All alternative scenarios would require strong public policies: food and nutritional policy to reorient food consumption, agricultural R&D policy, investment in agricultural infrastructures to improve water efficiency management, to reduce loss between harvest and consumption or to modify agricultural practices and systems. However, compared to the initial situation or past trends, reaching the targets involved in the Mediterranean diet, the Technical progress and the Reduced waste and loss scenarios will imply differentiated efforts across MENA sub-regions (Figs. 1 and 2).

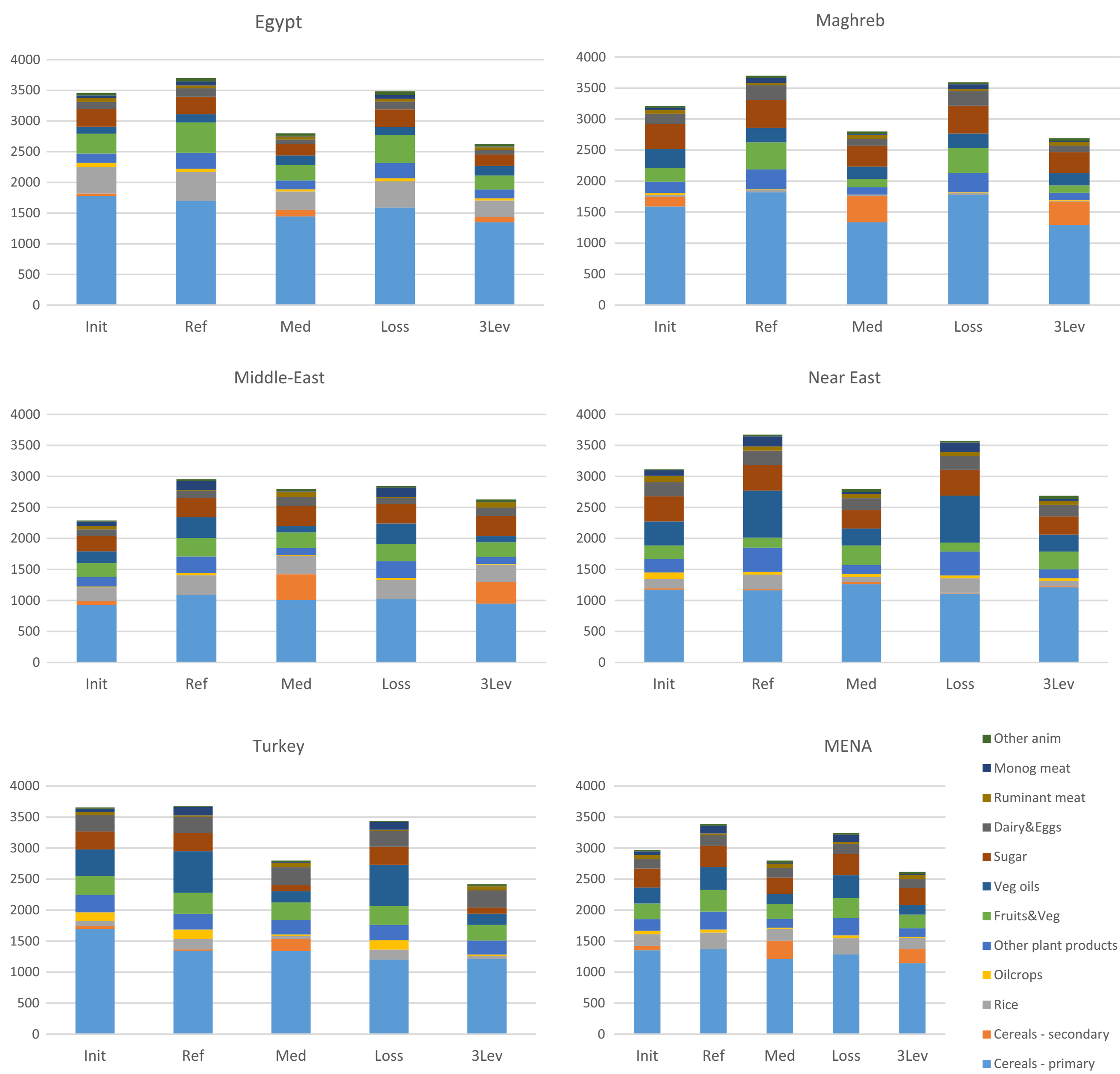

Fig. 1 Food diets in 2008 (Init) and in 2050 under the baseline scenarios (Ref and Ref CC) and the alternative scenarios Mediterranean diet (Med), Reduced waste and loss (Loss) and Three levers (3Lev), for the five sub-regions and for the MENA as a whole (kcal/cap/day) (source: authors' calculation based on data from FAOStat and FAO (2011))

The shift from the reference (Ref and Ref with CC) diet to the Mediterranean (Med) diet implies particularly significant decrease in food consumption in all sub-regions but the Middle East, where the nutritional transition is lagging behind relative to other sub-regions. Regarding the diet patterns, this shift induces less important changes except for some specific product categories in some sub-regions: increased secondary cereals in the Maghreb, the Middle East and Turkey; reduced vegetable oils in the Maghreb, reduced sugar in Turkey, reduced monogastric (poultry) meat to the benefit of ruminant (small ruminant) meat in all sub-regions. Comparing the reference diet and the diet with half less wastes on the consumption side (Loss) suggests that reducing these wastes by half would not induce so significant change for food consumers in the MENA, except for Turkey where such wastes account for a larger share of the caloric content of the diet (Fig. 1).

In the Technical progress scenario, we assumed that the adaptation of agriculture to climate change, supported by technical innovations and improved practices would allow

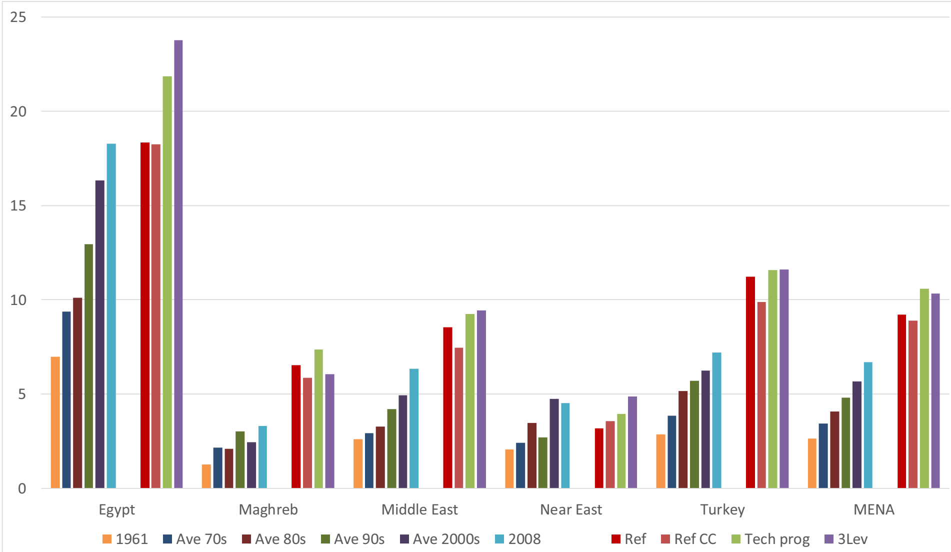

Fig. 2 Trends in yield over 1961–2010 and simulated yield in 2050 under the reference (Ref), the Technical progress (Tech pro) and the Three levers (3Lev) scenarios for the five sub-regions and the MENA as a whole (million kcal/ha) (source: authors' calculation based on FAOStat data (1961–2008) and simulation results (Ref, Ref CC, Tech pro and 3Lev)). Note: The change in total production per hectare across scenarios results from both the changes in assumptions involved in the various scenarios and the changes in the production pattern (and the resulting effect in terms of total amount of kilocalories produced) induced by scenarios

for increasing crop yields from their 2050 levels with the Ref with CC scenario to their 2050 levels with the Ref scenario. In other words, we assumed that the joint impact of adaptation of agriculture and technical progress would allow, in average, to compensate for the negative effects of climate change on crop yields in the MENA region. Comparing this ex ante assumption to ex post simulation results shows that the + 20% average increase rightly compensates for the negative impact of climate change for a few MENA sub-regions only (Fig. 2). Indeed, the scenario Technical progress (Tech pro) results in a total production per hectare recovering or slightly above the level it reached with the Reference scenario (Ref) only in the Maghreb, the Middle East and Turkey. For other sub-regions, and for the MENA as a whole, the Technical progress scenario induces a total production per hectare level that is significantly higher than its reference level. Indeed, according to our assumptions, climate change has no impact in Egypt and a slightly positive impact in the Near East. Therefore, in both sub-regions, the Ref with CC scenario does not make the production per hectare to decrease relative to the Ref scenario, and the Technical progress scenario does not compensate for climate change impact but implies a "net" + 20% increase of crop yields relative to the Reference scenario.

Finally, compared to the Technical progress scenario, the Three levers scenario involves in addition the reduction of post-harvest losses on the supply side and the shift to the Mediterranean diet on the demand side. This results in a stagnating or decreasing production per hectare relative to the Technical progress scenario in the Maghreb, the Middle East, Turkey and for the whole MENA region. But, once again, the Three levers scenario makes the production per hectare to further increase relative to the Technical progress scenario in Egypt and the Near East.

One could conclude that our + 20% increase in crop yields assumption is too optimistic and may prove difficult to achieve, at least for Egypt and the Near East. Our objective is to provide a range of possible situations in the MENA sub-regions in 2050 and Fig. 2 suggests that our + 20% crop yields increase assumption appears as in line with observed trends since the 1961 in all sub-regions. Hence, our assumption does not imply an acceleration of the pace of technical change compared to the 1962–2008 period. Of course reaching such crop yield levels in 2050 will require large amounts of investments in agriculture and will not be an easy task. However, past trends suggest that MENA sub-regions have already been able to reach comparable crop yields increase in the past (admittedly in a likely more favourable climatic context).

Results

Current trends likely contribute to increasing MENA's food import dependency

If the different components of the agricultural and food system of the MENA region (diet, crop yields, animal productivity, cultivable land area) as well as the domestic

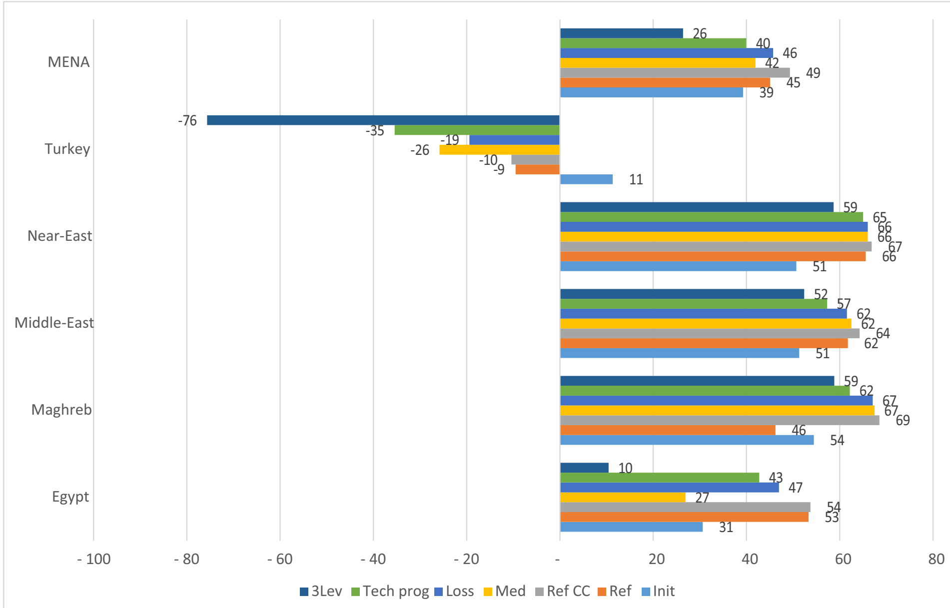

Fig. 3 Net import dependency of the MENA region and its five sub-regions in 2008 and in 2050 under the six scenarios (% net imports within total domestic consumption in kilocalories) (sources: FAOStat (Init) & simulation results (six scenarios))

population continue to evolve according to current trends without accelerated climate change (Ref scenario), the net food import dependency ratio of the region would rise from 39% in 2008 to 45% in 2050 (Fig. 3). The most strongly affected sub-regions would be the Near East and the Middle East, with import dependency at 66% and 62% respectively in 2050 (vs. 51% in 2008 in both sub-regions), and Egypt, with an import dependency at 53% (vs. 30% in 2008). Only the Maghreb and Turkey would be able to expand domestic agricultural production faster than domestic demand in this scenario, enabling the Maghreb to reduce its dependence on imports compared to the initial situation and Turkey to become a net exporter.

Furthermore, the negative regional impacts of climate change are likely to accelerate the rise of the MENA's food import dependency. Indeed, climate change will mainly affect crop yields but also the cultivable land area of certain parts of the region. Considering these impacts of climate change in the region (Ref with CC scenario), the net food import dependency of the MENA region could reach 50% by 2050. The Maghreb would be particularly affected, losing nearly half of its cultivable land and becoming dependent on imports for almost 70% of its needs in food and agricultural products. The Near East as well could lose a quarter of its cultivable land and its dependence on imports could reach 67% in 2050. The Middle East and Egypt would be less affected, the more severe impacts of climate change resulting in a slight increase in cultivable land in the Middle East and no change in production conditions in Egypt due to our assumption of continued availability of water for irrigation (Egyptian agriculture is almost completely irrigated). The food import dependency in both regions would reach 64% and 54% respectively with the reference scenario. Finally, Turkey could benefit from aggravated climate change with a 15% increase in its cultivable land and a strengthening of its net exporter position (Fig. 3).

Three levers for decelerating the rise of the MENA's food import dependency

According to our hypotheses, faster technical progress (Technical progress scenario) would have the strongest contribution with the MENA's net import dependency ratio in 2050 decreasing from almost 50% under the Ref with CC scenario to nearly its 2008 level 39%. Reducing waste and loss (Reduced waste and loss scenario) could help the MENA region to limit the rise of its food import dependency to 46%, while adopting a Mediterranean-type diet (Mediterranean diet scenario) would result in a 42% net import dependency ratio (Fig. 3).

But, none of the three options, taken individually, could significantly offset the increased import dependency in the most affected sub-regions. For the Maghreb and the Middle East, faster technical progress would be the most favourable, reducing dependency from 69 to 62% and from 64 to 57%, respectively. Reducing waste and loss would be second in terms of impact, with the potential to decrease import dependency levels to 67% in the Maghreb and to 62% in the Middle East. The Mediterranean diet option would have a relatively weak impact on import dependency levels in the end, but could have a beneficial effect on public health. The Near East appears as quite insensitive to the three options. Consequently, for the Maghreb, the Middle East and the Near East, only an integrated policy approach seeking to combine all these options would be effective in mitigating the rise in their food import dependency.

In contrast, the impacts of these three levers on Egypt are much greater and each of them allows this country to limit the rise of its dependency rate or maintain its level close to the initial situation level (i.e. 31%): 43% for the Technical progress scenario; 47% for the Reduced waste and loss scenario; 27% for the Mediterranean diet scenario.

All of these three options would further strengthen Turkey's position as a net exporter of agricultural products. Whereas Turkey becomes a net exporter in both reference scenarios, faster technical progress would enable it to export 35% of its total domestic use. This percentage would be 19% if waste and loss were reduced and 26% if a Mediterranean diet was adopted. Thus, Turkey could become a major supplier for the MENA region as a whole.

Combining the three levers would allow to mitigate the food import dependency rise in the three most dependant sub-regions: Maghreb, Middle East and Near East

Combining the three levers allows the three most dependent sub-regions, Maghreb, Middle East and Near East, to mitigate the rise of their food import dependency, dependence levels returning close to initial levels with the Three levers scenario. In Egypt and in the whole MENA region, the Three levers scenario induces a reduction of food import dependency relative to the initial situation (resp. 10% vs. 39% and 26% vs. 39%). Finally, combining the three levers makes Turkey to increase substantially its capacity of exports. Provided that export pattern of Turkey can match with domestic needs patterns of other MENA sub-regions, this suggests that Turkey could play a key role in the long term in becoming a leading food supplier within the MENA region.

Discussion and limitations

We used a biomass balance model accounting for physical flows under physical constraints for our simulations. In this kind of model, lack of domestic supply results from lack of cultivable area, which translates into decreased exports and increased imports of the region until satisfaction of domestic demand. It is thus different from a market and trade economic model in which lack of supply in one region translates into an increase in the domestic prices relative to world prices, depressing exports and boosting imports of the considered region. While the mechanism at stake is the same, the main difference between both types of models lies in the responses of exports and imports of individual products, which are differentiated across products in a market and trade economic model while there is no substitution between products and responses are mostly equi-proportional for all products in our biomass balance model. Hence, the structure of trade in GlobAgri-MENA is more rigid than in an economic model. However, our results converge with most of the literature that expects further growth in MENA's agricultural import dependence (OECD/FAO 2018; Tull 2020).

Our scenarios involve some restrictive assumptions, which require further work. A major limitation of our scenarios results from the difficulty to take into account water availability and its potential changes, and soil degradation processes, which are two major features facing MENA region's agriculture. The past observed data and the existing literature we used in order to derive our hypotheses on crop yields (Müller and Robertson 2014) and cultivable land (Zabel et al. 2014) account, at least partly, for these phenomena, but we do not know exactly to what extent. This is a crucial question in a region where water availability and soil degradation, already acute, are likely to increase and could lead to significant losses of cultivable land in areas such as the Nile delta, or limit the land equipped or equipable for irrigation (Tull 2020; Namdar et al. 2021). As already mentioned, our results relating to Egypt are highly dependent on the quite conservative hypotheses we adopted because of the lack of reliable and comprehensive information concerning these phenomena (SI materials and methods).

In general, quantifying our hypotheses regarding crop and animal yields in 2050 revealed a quite difficult task, though this difficulty is not specific to the MENA region. It is very hard to find comprehensive quantitative information on the potential future performance in either crop or animal production across the world. For crops, one difficulty is the lack of information on irrigated areas by crop. The difficulty is extreme when dealing with hypotheses on animal productivity changes in the reference scenarios. Indeed, there is very little information on long-term developments of animal efficiencies around the world, for both different species and different production systems. The work of Bouwman et al. (2005) on which we relied is one of the few existing references. But, it is clear that the work of collecting and assembling information and data on this subject must be increased because this information is absolutely crucial as regards the future of land use, greenhouse gas emissions and world food security (Herrero et al. 2013; Havlik et al. 2013; Faverdin et al. 2022).

Our simulation results depend on the retained assumptions in the various scenarios. Given the uncertainty regarding the ability of the MENA sub-regions to improve the productive performance of their agriculture, even more in a degraded climatic context, the results of our Technical progress and Three levers scenarios may be considered cautiously. More precisely, the extent of the impacts of both scenarios on import dependency ratios of MENA sub-regions (especially Egypt) must be considered cautiously. However, this does not call into question our obtained general result that with increased climate change impacts, only the combination of several levers through comprehensive and integrated policies could help the Maghreb, the Middle East and the Near East subregions to mitigate the rise of their food import dependency.

Conclusion

Existing trends in food consumption and agricultural production in the MENA will lead to a continued rise in the region's import dependency through the year 2050. Furthermore, the MENA dependence on imports will increase as the impacts of climate change are being felt in the region, in the absence of adaptation. Among the five sub-regions considered in this study, the Middle East, the Near East and the Maghreb will be the most severely affected, with net imports reaching 70% of domestic food needs. The situation will be less adverse in Egypt due to its current lower level of import dependency, but also due to our assumption of severe climate change not affecting irrigated land and yields. Only Turkey, thanks to its more favourable geography and initial position in terms of import dependence, has the potential to become a net agricultural exporter, with a significant share of domestic production potentially available to supply regional and international markets. This suggests that developing MENA intra-regional trade could help to manage the impacts of climate change, with Turkey as a potential leading supplier of the MENA region.

The economic and political risks of reaching high levels of agricultural import dependence are well known: trade imbalances, increased national debt levels, strong exposure to global market fluctuations, recurrent food crises, political instability, etc. The large volume of agricultural products involved, moreover, weighs heavily on international markets and can have an impact on prices of critical agricultural commodities such as wheat. Risks of price escalation can in turn create tensions and difficulties for internal markets, national food policies and the issue of food accessibility for poor populations, with potential consequences in terms of international migrations. The measures envisaged here to mitigate the rise in agricultural dependence of the MENA (stimulation of agricultural production, regulation of food demand, improved management of food waste and loss) will require ambitious public policy interventions and significant levels of monetary investment and will be of limited impact if they are not pursued as an integrated, multifaceted strategy.

In addition, the import flows needed to supply the region's food systems and trade prices are very sensitive to tensions that may develop among trading partners supplying agricultural goods. Today, a large and growing proportion of these goods come from countries of the former Soviet Union (notably Ukraine, Kazakhstan and the Russian Federation). The tensions and conflicts that develop there will therefore have serious repercussions on food supplies in the MENA region.

As we have seen, Turkey can help supply the other countries in the region by becoming a net exporter by 2050. Nevertheless, and beyond the internal geopolitical stakes in the region of this reorientation of trade, the volumes that Turkey would be likely to supply will be too small to compensate for the drop in supply from the large producer countries of the former Soviet Union.

There is therefore a strong challenge for MENA countries to develop agricultural and food policies that aim to reduce their dependence on agricultural imports and/or the vulnerabilities associated with such dependence.

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Data Availability https://entrepot.recherche.data.gouv.fr/dataset.xhtml?

Declarations

Conflict of interest The authors declare no competing interests.

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