4.2.5 Main assumptions

The vulnerability and impact assessment assumes that the policies and strategies currently in place will be on the course to implementation by 2030. It is assumed that the decreed NPMPLT and future changes to occur under its umbrella are part of the future baseline scenario without climate change.

However, the analysis does not account for internal and external security shocks which would severely impact growth, the population's livelihoods and vulnerability, hence intensifying any natural shocks from the projected climatic changes.

4.3 Vulnerability & Adaptation of the Agriculture Sector

Due to the topography of the Lebanese territories that allows for a distribution of precipitation ranging widely from less than 200 mm to more than 1,400 mm of rain per year, five distinct agro-climatic zones are present. The varied elevation offers Lebanon the possibility of extending to an extremely diversified agriculture; from quasi-tropical products on coastal plains to orchards in high-altitude mountains. The main crop production regions are the coastal strip, the Akkar plains, the central Bekaa valley, the mountainous region, the western slopes of the Mount Hermon and Anti-Lebanon range and the hills in the South (Saade, 1994).

Population growth exerts pressure on agricultural production where the higher demand for food leads to more intensive agricultural practices that are characterized by the excessive use of fertilizers and increase in the use of water for irrigation. Projections through 2030 show an increase of 41% in total domestic demand for water (from 296 Mm^3 in 2000 to 418 Mm^3 in 2030), and estimate the need for irrigation water at 1,600 Mm^3 (CDR, 2005). According to the Ministry of Environment (2001), 32% of water resources available for exploitation in 2015 will be directed towards domestic use (as compared to 16% in 1994), leaving 60% of water resources to agricultural use (as compared to 74% in 1994). It is worth noting that water withdrawal figures for 2005 show that the share of agriculture had already dropped below 60% (FAO, 2010). Other projections elaborated in the National Integrated Water Resources Management Plan for Lebanon (Hreiche, 2009) forecast a 47% increase in the irrigated surface area by 2030 (2005 as a base year), and a 10% increase in the demand for irrigation water. The total need is estimated at 1,410 Mm^3 in 2030, versus 1,600 Mm^3 estimated by CDR (2005).

4.3.1 Methodology

Scope of assessment

The overall vulnerability of crops and sub-sectors was evaluated according to their economic importance, their exposure and sensitivity to the changing climatic conditions projected for Lebanon and the adaptive capacity of the farming system (land, labor, irrigation systems, etc.) in the two baseline socio-economic scenarios. Livestock and crops that are totally dependent on the amount of rainfall such as grazing small ruminants, rainfed crops (olives, grapes and wheat), crops whose production is highly vulnerable to temperature changes (stone and pome fruits) and crops that require a large initial investment with long payback periods (perennial crops), are prioritized. Water demanding crops, such as bananas, tomatoes and potatoes are also selected for vulnerability assessment. Citrus crops as well as avocado were not considered since they are less vulnerable to climate change, given that they are tropical crops.

References on crop climatic needs were linked to projected climatic conditions in order to predict the vulnerability and impact on specific crops. Climatic simulations were adjusted according to the agro-climatic zones where specific crops are grown. Eventual impacts of climate change on specific crops were retrieved from available studies on Mediterranean countries, namely Italy, Tunisia and Greece, or countries with similar climatic conditions, namely Australia, South Africa and the state of California of the USA, whenever possible.

The assessment covers the entire country with focus on the areas where the target crops and fruit trees are produced. The analysis is done on a yearly basis for annual crops such as cereals and vegetables, and on a two-year basis for perennial crops, such as olives. The impact of climate change on the vitality and survival of young non-productive seedlings and trees is also important, especially during the first four years after planting. A period of 25 years with 2005 as baseline year is adopted for the analysis of vulnerability.

Development of the sector under socio-economic scenarios

Under Scenario A, population remains almost the same meaning that overall food demand remains the same corresponding to a low increase in local consumption needs. Local agricultural production might slightly decrease as more land and water are allocated for urban areas. The cost of production might increase due to low investment in agricultural capital. Looking at the figures of Scenario A, assumptions are that the future situation will follow current trends. The growth in international trade, increased globalization and increased competition coupled with a weak development of export-oriented crops signal a slight growth in agricultural and food exports.

Under scenario B, population growth will exert more pressure on agriculture in two ways; (1) more intensive production, and (2) more expansion of residential areas over agricultural lands. Although local production will be better positioned to resist rising food import levels, imports especially for non-essential food needs will grow, while the demand of essential food products will be increasingly met from local production (e.g. dairy and meat products, vegetable oil, sugar and cereals). More pressure will be exerted to satisfy the local consumption needs; and with increasing demographic pressure, the stress is mainly on water demand which means that farmers will have to adopt drip irrigation systems to increase water use efficiency. However, improvement in yields will not correspond to the rising demand of a larger population growth but to the increased adoption of technology. Land prices will increase in tandem with population growth, which would disfavor agricultural land use. Despite the projected rise in yields; local production will continue to face increasing competition, and the high local production costs are expected to render local produce uncompetitive.

4.3.2 Vulnerability and Impact Assessment

Sensitivity and adaptive capacity are examined for the most vulnerable crops, and an analysis of the vulnerability is presented for each of the crops and agricultural sub-sectors. The impacts of projected changes in climatic conditions and changes in socio-economic conditions use indicators of productivity, cultivated area, need and cost of irrigation, and volume and value of export in order to provide a targeted impact assessment that could potentially be measured in the future. The impact assessment is carried out in light of the socio-economic scenarios A and B, and is based on expert judgment and supported by a review of the scientific literature.

Wheat

The overall vulnerability of wheat and cereals in general to projected changes in relevant climatic factors is considered moderate since wheat yield is mostly correlated to rainfall amount (minimum annual rainfall should be above 400 mm), T_{max} in November and T_{min} in March (Ventrella, 2006). The most vulnerable areas in Lebanon are in the Bekaa where extreme conditions such as reduced precipitation and frost are more frequent. Since spring rainfall is more prejudicial than annual overall rain amount, areas where rainfall attains more 800 mm/yr are still considered with moderate risk.

Changes in temperature and precipitation patterns do not show a significant effect on the production of wheat in Lebanon. Higher spring temperatures and higher evapotranspiration (ETP) will decrease soil moisture and increase aridity that will reduce yields in the second half of the century, especially if rain or complementing irrigation does not occur in spring. Since the onset of the rainy season defines sowing date, all areas of production will be facing a shorter period of growth. All areas of wheat production are subject to yield variation, but yield variation is very controversial and difficult to assess.

Potato

Potato is cultivated all year round, mainly in the Bekaa (during spring/summer) and in Akkar (in winter). It is 100% irrigated in the Bekaa while irrigation is complementary to rainfall in Akkar (MoA and LARI, 2008). Production is affected when temperature is outside the range of 10-30˚C. Hence, winter cropping of potato in Akkar is vulnerable, with higher frequency of disease due to higher humidity and milder temperatures. On the other hand, spring and autumn cropping in the Bekaa are mostly affected by water availability and temperature extremes, while summer cropping is highly vulnerable as tuber formation could be jeopardized, and irrigation lacking. Figure 4-12 illustrates the cultivation areas and vulnerability of the potato crops to projected changes in climatic factors with a ranking of vulnerability by area. The overall vulnerability of the potato crop is considered high.

Currenlty, potato is tolerating summer heat and slight winter frost in the Bekaa, as cool, summer nights are enough for starch accumulation, and winter sunny days are suitable for plant growth. Projected changes in climate will decrease the risk of frost to less than 1 day per month for the three winter months, and increase the average T_{max} to above 30˚C starting May. This could be seen as an opportunity to plant potatoes as a winter crop, rapidly increase canopy, save water for irrigation, harvest earlier and increase yield (Haverkort, 2008). Nevertheless, potato cultivation in spring and summer will be unsound as T_{min} in summer nights will increase (T_{min} above 20˚C), and water for irrigation will be scarce, while plant demands will be higher. It would become possible though to plant a second autumnal crop from September to December. Potato growers will see their profits increase from early cropping, but might lose if they plant later in the spring/summer season. Winter potato growers will be facing nematodes and aphids infestation and more fungi and bacterial diseases, such as late blight, brown rot and erwinia due to the combined relative humidity and temperature increase (Haverkort, 2008).

Tomato

Tomato is as an annual crop cultivated, mainly in the Bekaa valley, Akkar plain, Zahrani plain, as well as coastal areas and mountain villages of Mount Lebanon and North Lebanon. It is grown either in greenhouses or in fields, mostly as an irrigated crop and requires a warm and cool climate. The tomato plant cannot withstand frost and high humidity hence requires temperatures between 10˚C and 30˚C. Field tomato is grown in 2 rounds in the Bekaa and on medium altitudes (500 - 1,200 m) between April and August and on higher altitudes (1,200 - 2,000 m) between May and the first frost in autumn while it can be gown for up to 3 rounds per year in greenhouses. The overall vulnerability of the tomato crop is considered moderate where the vulnerable areas of production are in medium altitudes including the Bekaa and Marjayoun plains and in coastal areas where tomato production could be relocated.

Tomato production would be slightly affected by temperature rises by the 2030s, but yield decrease could be significant by the end of the century. The growing period would be shorter, with less fruit set in summer due to temperature extremes, and water shortage, especially in the Bekaa and mid-range altitudes. On higher altitudes, the diminishing production in summer could be counterbalanced by a delayed autumn frost. Water demand of plants would increase and water availability for irrigation is likely to decrease especially on coastal areas that are highly affected by seawater intrusion in groundwater. Increasing carbon concentration in the air would offset eventual production losses in tomato crops grown in plastic greenhouses due to higher temperatures and relative humidity during the spring and summer/ autumn growing seasons. Under Scenario A, overall productivity is not expected to change, despite the regional differences, while under Scenario B, productivity might actually increase due to increased adoption of technology which would counter effect the expected slight decrease in productivity.

Cherries

Cherries are grown in Lebanon in temperate regions, mostly in Mount Lebanon and the Bekaa. Orchards are mainly irrigated except in Aarsal where they are rainfed. Due to several problems in cherry production on lower altitude areas such as wood insect outbreaks, spring frost, and deficient chilling requirements, the more drought tolerant rootstock Prunus mahaleb is currently being used to enable the production of rainfed or complementary irrigated cherries. Cherry blossom is sufficiently robust against short spring frost, however due to its high chilling requirements (700 hours of chilling which is equivalent to 70 days with 0˚C< T_{min} <7.2˚C), it is likely to be more sensitive to high temperatures (over 21˚C) in winter and during blossom as well as early hail and rain. The overall vulnerability of the crop is considered moderate, with the central Bekaa being highly vulnerable.

With the expected increases in minimum temperature, chilling needs of cherries will barely be met by 2024 (630 hours), and would be below requirements by the end of the century (444 hours). Increases in maximum temperature will increase the risk of failure of blossom pollination and fecundation by 30% in Mount Lebanon and up to 50% in the Bekaa valley and will increase the rate of infestation by the cherry fly especially with high spring temperatures. These risks are lower at altitudes higher than 1,300 - 1500 m. The changes in precipitation amount and number of rainy days in spring will not affect significantly rainfed orchards even if soil moisture is slightly reduced. If irrigated orchards are to face a shortage in water due to higher demand in other sectors and higher ETP, the production will be slightly affected. As for the drought-resistant Mahaleb rootstock, the growth of its fruit occurs in spring when the soil is still moist; hence, it will not be affected by the decrease in irrigation water resources. Overall, cherry crops grown in central Bekaa at altitudes below 1,300 m will be less productive with time.

Apples

Apple is the most cultivated fruit species by area, and is the second highest agricultural product marked for export (MoA, 2007). Apple plantations are located mainly in North Lebanon, Mount Lebanon and the Bekaa, in altitudes between 900 m and 1,900 m. Production is sensitive to spring

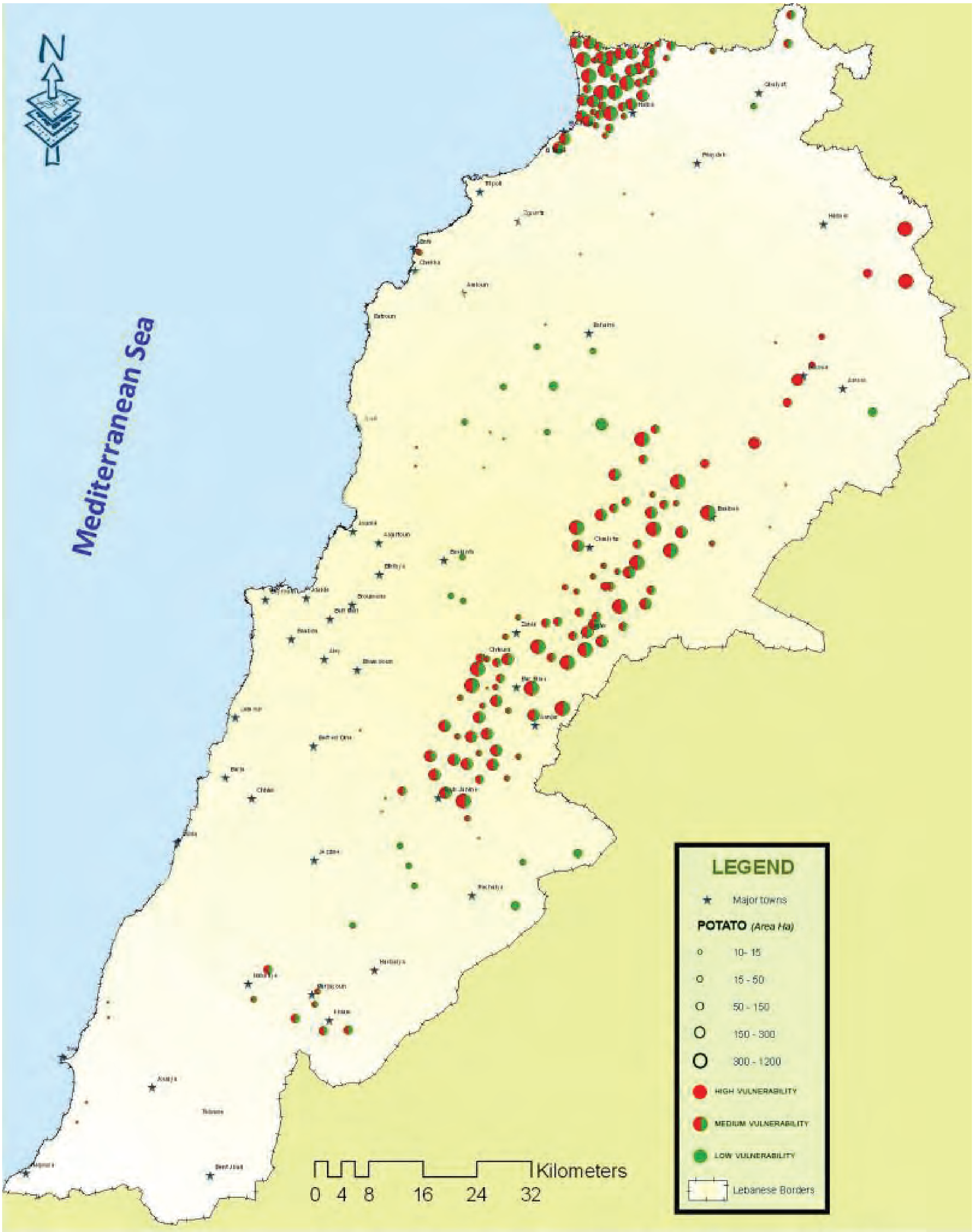

Figure 4-12 Potato cultivation areas and crop vulnerability

frost, hot and dry winds, and hail and rain that come late in May or June or later in October, as well as high temperatures (>40°C) accompanied with drought conditions, and less cloud cover, all increase the risk of sunburn to fruits (Trillot et al., 2002) that affect the apples' chilling requirements (400 to 900 hours) (Steffens and Stutte, 1989). In Addition, demographic pressure in Akkar, the Bekaa and some other areas combined with water scarcity for irrigation will intensely affect the production. Figure 4-13 illustrates the cultivation areas and vulnerability of apple trees to the projected changes in climatic factors with a ranking of vulnerability by area. The overall vulnerability of the apple trees is considered high.

Increases in temperature are expected to reduce the chilling requirements of apple cultivars at 1,000 m elevation from 678 hours to 444 hours by the end of the century. Changes in precipitation patterns will not directly affect production since in general apple orchards are irrigated. If a shortage in irrigation water occurs with increase in ETP and water demand, production will be affected. Since water needs for apples are mostly during the fruit growth period between May and July, it is estimated that reduced irrigation supply will increase the rate of fruit drop and reduce fruit caliber. A shortage in water later in August or September would slightly affect fruit quality. If water flow is to decrease by 20%, the yield (or area) of apple trees will drop by 10 to 15% at least. As cloud cover and relative humidity do not show a significant change, fruit quality, consisting of fruit color, russet and sunburn among others would not face additional risks. Nevertheless, late varieties planted in the Bekaa valley are more prone to sunburn due to excessive sun radiation, lower relative humidity, higher temperatures and higher frequency of heat waves.

Grapevine

Most of the area of production of grapevine is located in the Bekaa valley and Akkar, with few vineyards in Mount Lebanon and the South. Vineyards for table grape production are irrigated in general, while industrial production is rainfed (MoA and LARI, 2008). Most varieties are local and area specific. For instance, the Maghdoushi variety is better adapted to warm areas, while the Tfeifihi and Baitamuni varieties thrive better in cooler regions. However, in general, grapevine requires a long warm summer and a mild winter, tolerates drought and can survive rainfall of no more than 300 mm a year. Humid spring and summer seasons would negatively affect yields and the quality of the crop. Table vines can tolerate high T_{max} over 40°C, yet heat waves should not last days as fruit quality will be altered when T_{max} is over 30°C. Vines can stand winter frost too, but are sensitive to spring frost. Humidity and cool temperatures (below 15°C) negatively affect fruit set (Schultz et al., 2005; Vidaud et al., 1993). The overall vulnerability of the grapevines crop is considered moderate.

Climatic projections show that T_{max} will be the major limiting factor for table grapes in both the Bekaa and Akkar, where higher temperatures may lead to 1) early bud burst thus increasing the vulnerability of to eventual spring frosts (Quirk, 2007) 2) early Véraison stage thus exposing fruits to sunburn and causing early ripening. For rainfed table grapes and industrial grapevines, changes in precipitation will affect production and quality of grapes especially in low altitude areas, leading to an eventual decrease in yields and a change in wine quality. Since there is no information about the capacity of the actual system of production, such as rootstock, variety, distance of plantation, training system and soil cover, to cope with climate change, losses in terms of production are not evident, except that quality will certainly be affected. In general, grapevine production could face several problems in terms of water availability for irrigation and in terms of quality, especially for industrial grapes, due to temperature rise. Thus, all the areas of production are vulnerable.

Banana

Production of banana is concentrated mainly on the coast of South Lebanon and to a lesser extent in Mount Lebanon (MoA, 2007), on altitudes rarely exceeding 150 m mostly due to the lack of water availability at higher altitudes. Banana is usually planted for a two-year growth period and requires heat, humidity and large amounts of irrigation water to ensure its needs during the arid season. It cannot withstand frost. Banana production may be hindered by a reduced land and water availability due to urbanization, demographic pressure and seawater intrusion in coastal aquifers. Nevertheless, the climatic conditions will be favorable for banana growth and even expansion further north to its actual limits in latitude and even in altitude, which will counterbalance the losses. Therefore, the overall vulnerability of the crop is considered lowThe climate conditions predicted for the near and distant future are likely to be favorable for banana production. Increases in temperature, humidity and carbon fertilization would have a positive impact on yields and fruit quality. Banana plantations could be expanded to higher altitudes (by 150 m at least) and further north in latitude to the Syrian coastal plain.

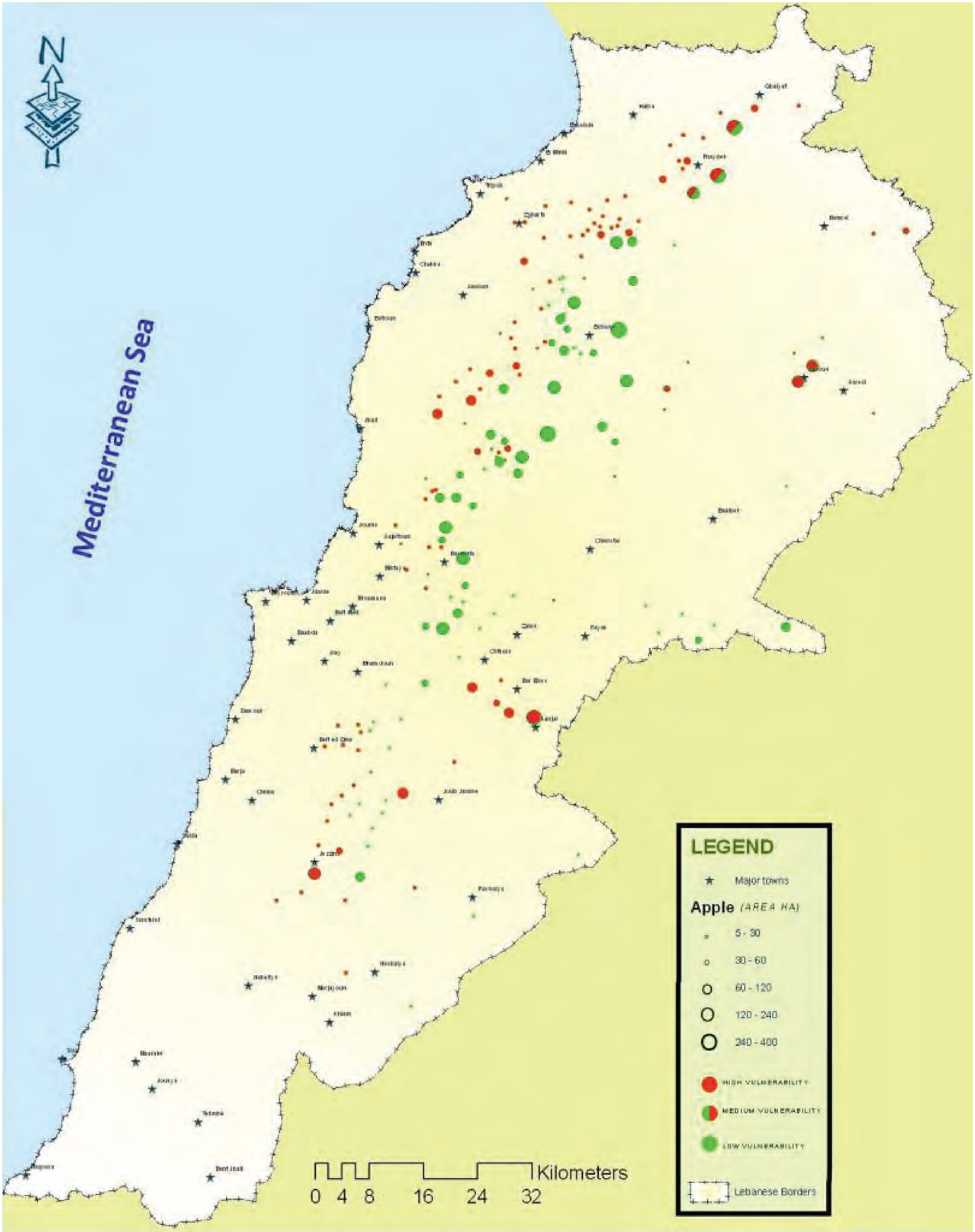

Figure 4-13 Apple cultivation area and crop vulnerability

However, water demand in addition to the frequency of nematodes, viruses and fungal diseases is expected to concurrently increase.

Olive

Olive tree orchards are generally found on the western slopes of Mount Lebanon and Mount Hermon below 1,000 m. They are mostly rainfed, except in areas that receive less than 300 mm of annual rainfall, such as in Hermel. Since Lebanon is a major importer of vegetable oils, it is important to consider the olive crop grown for oil production as an important crop for food security that helps the population meet its fat intake. The olive tree can withstand long drought periods, high temperatures (above 40˚C) and low precipitation thus water needs in the summer time are minimal, and can be secured through the tree's high performing rooting system. Olives are sensitive to long cold waves, freezing winter temperatures (below -5˚C), spring frosts and hot dry winds (MoA and LARI, 2008; Loussert and Brousse, 1978). The major climatic factors that would eventually affect olive production are the amount of precipitation and to a lesser extend chilling requirements. Some pests and disease will be reduced with higher temperatures and drier weather, which leaves most areas of production at low risk. In areas at altitudes higher than 500 m, the olive groves will always receive enough precipitation for proper yields and ensure their chilling needs. The area of cultivation could even expand to higher altitudes of up to 1,300 m as warmer temperatures set in. The overall vulnerability of the olive crop is considered low with plantations on costal zones and in northern Bekaa being the most vulnerable due to persisting humidity, decrease in chilling hours, demographic pressure and decrease in water availability where olive groves are irrigated.

The impact of climate change on olive production is limited to 1) a slight reduction in yield by the end of the century in areas with minimal precipitation rates due to a decrease in rainfall and decrease in the chilling period (from 37 days to 4 days) which will however be partially offset by carbon fertilization and 2) proliferation of the olive fly and olive moth. In general, olive tree cultivation will be slightly affected. The vulnerable areas of production in the Bekaa do not constitute more than 5% of the total olive cultivated area, and are mostly irrigated. Large olive groves in areas below 500 m, specifically Akkar, Zgharta, Koura, Batroun, Saida, Tyre and Nabatiyeh, will face reductions in yields.

Small ruminants

Small ruminants include sheep and goats in Lebanon which are concentrated in the Bekaa valley, and in summer migrate between the valley and the surrounding mountain chains. Rangelands provide the bulk of livestock food needs in Lebanon. However with the absence of natural permanent pastures, shepherds invest in forests, other wooded lands and in agriculture areas, specifically post-harvest fields and fallows. The degradation of vegetation cover in many rangelands in Lebanon is an evidence of overgrazing. In other areas, forest biomass is increasing and forests and woodlands are invading grasslands, as there is a lack, and even an absence, of herds in these areas. Since grasslands are scarce, shepherds are increasingly relying on feed blocks and feed supplements to complete the nutrient ratio of the ruminants, hence decreasing the vulnerability of animal production to climate change, since the feed is provided regardless of the availability of grazing (Enne et al., 2002). Some ruminants such as local Awassi sheep and Black goat can adapt to these extreme conditions in terms of temperatures and drought and can still produce milk and meat although with reduced productivity (Gintzburger et al., 2006). However the overall vulnerability of small ruminants and rangelands is considered high.

The expected decrease in amount and distribution of precipitation coupled with an increase in temperatures may affect the length of the grazing period and the quality of pastures by increasing ETP and reducing soil moisture content and the viability of grass (Fleischer and Sternberg, 2006). Temperatures below 10˚C will slow down grass growth, and stop it when frost occurs. Higher levels of CO_2 will worsen conditions for grazing across the country as this will increase the carbon to nitrogen ratio in forage, thus reducing its food value and the carrying capacity of pastures. Moreover, a reduction in moisture availability would change the species composition in favor of woody, less palatable plants. A further effect of a shift of carbon storage from soil to biomass may adversely affect soil stability and increase erosion. Moreover, the shorter pasture season on the lower altitudes (below 1,000 m) would be partially compensated by an increase in herbaceous biomass due to optimal temperature and humidity conditions, coupled with carbon fertilization and an extension to medium altitudes. On higher altitudes (>2,000 m), herders would benefit from a longer pasture season caused by reduced thickness and a lower residence time of snow cover, but with a decreasing herbaceous biomass. By the 2080s, areas having an annual precipitation below 400 mm in the Bekaa will be facing additional reduction in rainfall (up to 35%), which would hamper the development of agriculture and grasslands would move southward in the northern Bekaa plain to invade abandoned agriculture areas.

Adaptive Capacity: agriculture resilience and food security

Several studies show that a better adaptation and resilience to climate change can be obtained through farm product diversity and small scale farming (Reidsma and Ewert, 2008; Oxfam, 2009). The Lebanese agricultural production is very diverse at both country and regional levels, due to the diversity of agro-climatic zones. Even at farm level, diversity is illustrated by the variety of grown crops (mainly for fruits and vegetables) and the range of cultivars within the same crop (namely fruit trees). The average surface of exploitations does not exceed one hectare. Although most farmers do not grow crops for their subsistence, at least one-third of the production is auto-consumed in small exploitations (MoA and FAO, 2005b). No cash crops are grown exclusively for export, which induces a more resilient market against international prices fluctuation. Most farmers do not count exclusively on agriculture for their livelihood. If this activity remains a primary source of income for most farmers, their livelihood is in most cases sustained by other income-generating activities.

In terms of food security, Lebanon produces half of the population's consumption in terms of value. The value of exported commodities such as fruits and vegetables partially covers the value of imports (namely cereals, meat and dairy products, sugar and vegetable oils). The food security balance tends to show more disequilibrium with increasing imports and demographic growth that cannot be covered by a notable increase in exports (MoE and AUB, 2009). Strategic crops for food security in Lebanon can be reduced to wheat, potato, poultry and red meat, milk and olive oil. While Lebanon is close to self-sufficiency in poultry meat, olive oil and potato, the country imports half of its needs of milk, and most of its consumption of red meat and vegetable oils. The production of exportable crops such as citrus crops, banana, apple, potato and tomato as well as some other fruits and vegetables are expected to decrease for multiple reasons including demographic pressure and climate change.

4.3.3 Adaptation measures

The key adaptation measure for climate change is setting and implementing a sustainable agriculture policy to sustain the viability of the agriculture sector, and maintain an acceptable level of food security. Although adaptation measures vary horizontally according to the agricultural sub-sectors and their vulnerability to climate change and vertically according to the different actors involved, they should be coherent and synergic to ensure a proper policy development and implementation. In addition, since the agricultural sector is considered as an emitter and a vulnerable sector, many measures proposed for mitigation can be applied for adaptation.

4.3.3.1 Field level measures

- Change planting dates and cropping pattern, according to precipitation and temperature variations and irrigation water availability;
- Shift to less water consuming crops, e.g. barley instead of wheat, snake cucumber instead of cucumber, figs instead of kaki, grapes instead of peaches; and drought and heat tolerant e.g. industrial hemp, avocado and citrus instead of banana;
- Adopt adequate plantation schemes and greenhouse systems in order to facilitate air circulation between plants in areas where atmospheric humidity is expected to increase, e.g. coastal plains;
- Introduce crops that would be tolerant to higher levels of humidity and temperature (i.e. citrus, tropical fruit trees), and to higher salinity concentrations (i.e. legumes, cucurbits and solanaceous rootstocks), especially in coastal zones;
- Shift to perennial crops (apple, cherry, and to a lesser extent other stone fruits, olive and grape) with low chilling requirements in lower altitude areas of cultivation of each crop;
- Shift to irrigation systems that are more efficient such as drip irrigation or sprinklers, and adjust irrigation schedules as well as water quantities according to the increasing crop water demand;
- Adopt sustainable agriculture practices such as conservation agriculture, adequate crop rotations (including fodder species) and organic farming;
- Adopt integrated pest management techniques, and good agricultural practices when organic farming is not an option, to decrease chemical use and lower the cost of production;

Table 4-4 Specific field level adaptations measures

Crop	Measures
Potato	Shift to winter cropping (plantation: December-February) and to a lesser extent autumn late cropping in the Bekaa (plantation: September) if water is available. In Akkar, plantation can be made earlier (December-January) Introduce early varieties that would have smaller vegetative period (Binnella, Charlotte, Samba, etc.). Late varieties could be kept if they are grown as winter crops and resistant to blight (Agria), or to drought (Remarka). Spunta which is the major grown cultivar should not comprise the bulk of the production Promote potato growing at higher altitudes (above 1,400 m) in small irrigated plains inland (Marjhine, Jbab el Homr, Oyoun Orghosh, Ainata, Yammouneh, Bakka, Yanta, etc.) and in the western chain of Mount Lebanon (Mrebbine, Laqlouq, Bakish) Adopt biotechnology to produce potato seeds locally
Cherry	Introduce Cristobalina, Brooks cultivars and maintain the early local cultivars (Nouwari, Telyani) at altitudes between 1,000 m and 1,300 m Select high performing clones of Prunus mahaleb or other equivalent rootstock
Apple	Introduce varieties such as Mollie's Delicious, Anna, Ein Shemer, and Dorsett at altitudes below 1,200 m and Gala, Granny Smith, Pink Lady, at altitudes between 1,200 m and 1,500 m Research on products inducing bud break and blossom to substitute for chilling requirement (i.e. Thidiazuron) in years with warm winters (Austin & Hall, 2001)
Grapevine	Promote early varieties of table grapes especially in lower altitudes (Early Superior seedless, Maghdoushi) instead of standard varieties (Baitamuni, Tfeifihi) Select drought and heat tolerant rootstocks (R110, 140Ru, P1103) and varieties from local and imported genetic resources, and disseminate to farmers Shift vineyards of Western Bekaa to higher altitudes (above 1,200 m) in potential areas such as Rashaya, Bhamdoun, higher Akkar, etc., for both table and industrial grapes
Olive	Promote new methods of harvesting to reduce bud alteration by traditional harvesting methods, and to reduce labor cost Upgrade post-harvest techniques (olive and oil storage, pressing) Undertake a policy based on the cost efficiency analysis of irrigation of olive orchards
Banana	Promote the use of shade nets to reduce transpiration and extreme climatic effects (hail, wind)

- Adapting the number of livestock according to the carrying capacity of a rangeland;
- Elaborating a national rangeland program in collaboration with all concerned actors, which would include concise specific rangeland management plans, with the eventual actions to be undertaken (grazing period, number of ruminants, etc.);
- Enhancing genetic selection of local breeds so they are adapted to local extreme climatic conditions and crossing them with breeds that have a higher potential of milk or meat production;
- Diversifying animal production through expanding into milk, dairy products, meat, leather, wool and honey;
- Promote mixed exploitations, e.g. animal and vegetable production;
- Promote controlled grazing in forests, namely in ecosystems that are prone to fires.

Specific adaptation measures for some crops are summarized hereafter in Table 4-4.

4.3.3.2 Research and infrastructure measures

Research measures

Some topics to be studied include conservation of agro-biodiversity by the creation of a gene bank; models tackling the potential agriculture production systems that could adapt to climate change; water consumption and needs of various crops and cultivars, and their variability with climate change, agriculture production systems and regions; socio-economic models that would engage water price efficiency according to the cultivated irrigated crops, i.e., virtual water price; tree training and pruning techniques to reduce alternate bearing between years; the nutritional value and the carrying capacity of different types of rangeland at different climatic conditions; and monitoring of meat and milk productivity of small ruminants according to the animal pedigree, type of rangeland and climatic conditions.

Infrastructure measures

Public institutions should rehabilitate their infrastructure to address operational inefficiencies (quarantines, laboratories, frontier posts, etc). Infrastructure related to the agriculture sector, which mostly occurs at farm level, includes water harvesting and distribution systems (dams, hill lakes, reservoirs and channels), terraces, greenhouses, agricultural machinery, agro-processing plants, storage and packaging units, hives, farm constructions, etc. The Green Plan at MoA, which is the mandated authority to provide such services to farmers on a demand-driven basis, should be reinforced.

An adaptation action plan for the agriculture sector is proposed in Table 4-5.

4.3.4 Cost of adaptation

The cost of adaptation at farm level would be impossible to address since measures are not limited in time, and the number of exploitations and actors involved are tremendous and heterogeneous. Some measures (such as changing planting dates, shifting varieties, no-tillage, crop diversification) are costless and comprise mainly operations that do not necessarily pose an additional cost to farmers. Other measures require additional investments such as irrigation systems, new rootstocks, adapted greenhouses and farm infrastructures, adapted machinery for seeding, weed control and harvesting in no-tillage systems, etc. The costs of these inputs, with the necessary labor needs are unpredictable because they depend on the scale of investments and baseline conditions at the farm level. However some of these measures are already being implemented regardless of climate change, to improve yields and product quality, or to decrease the cost of production.

The cost of adaptation at the level of public institutions, notably education, research and assistance, public infrastructure and institutional measures, is seen as an integral part of the national agriculture strategy. The budget line of adaptation is thus already included within the strategy, which means that only additional budgetary requirements should be addressed.

4.4 Vulnerability and Adaptation of the Electricity Sector

Although Lebanon figures among the countries with high coverage of electric power in the region (IEA, 2006), self-generation still plays a large role in electricity supply and demand due to the inability of EDL to meet demand effectively (World Bank, 2008). Expected changes in weather pattern due to climate change are only expected to exacerbate the already existing problems affecting the electricity sector in Lebanon.

4.4.1 Methodology

Scope of Assessment

The main aspects of vulnerability of the electricity sector focuses on 1) the increased pressure on the energy production system as a result of increased cooling demand during summer, increase in oil/gas prices and potential disruption of hydroelectric power plants as a result of reduced precipitation and 2) the increased pressure on the power supply chain as a result of increased demand, and possibly storm surges.

The assessment covers the entire country during summer and winter, since cooling and heating demands, hydropower generation, and power supply cover the whole territory and all seasons. The year 2004 is used as the baseline year and the analysis extends until 2030.

Methods of Assessment

The expected increase in temperature estimated by the climate model is used to calculate the increased energy demand in summer. Assuming an average Coefficient of Performance (COP) of 2.8, an average outside temperature between 13.6°C for January to 28.7°C for August (MoPWT, 1971) and an inside temperature of 22°C, an increase of 1 to 3°C in temperature by 2040 is estimated to lead to an annual increase in electrical cooling consumption of 9.04% to 28.55%. No projections are made for the 5°C increase in temperature by 2080-2098 since it is difficult to predict energy demand by then.

The increase in demand from natural and economic growth from 2004 to 2030 is estimated using expert judgment in the absence of data on activity level, energy intensity, etc. to make a disaggregated end-use oriented demand analysis and projections using LEAP. The additional growth in energy consumption resulting from increased cooling demand in summer is calculated for 2004 to 2030 and superimposed on the business-as-