2. VULNERABILITY AND ADAPTATION OF THE AGRICULTURE SECTOR

2.1. VULNERABILITY ASSESSMENT

2.1.1. Background

The topography of the Lebanese territories allows for a distribution of precipitation that ranges widely from less than 200 mm to more than 1,400 mm of rain per year. As a result, five distinct agro-climatic zones are present in the coastal strip, low and middle altitudes of Mount Lebanon, west, central and north Bekaa.

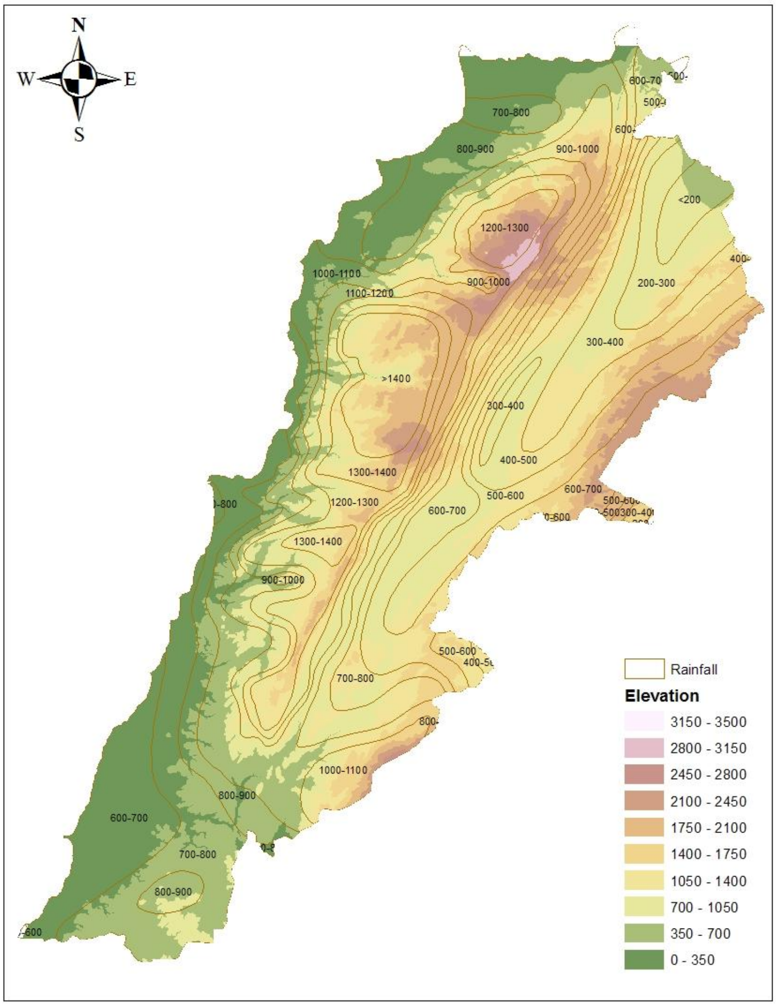

Figure 2-1 Pluviometric and topographic profile of Lebanon

Topography is a determining factor for potential crop types and agricultural techniques. Other factors include the characteristics of soils, irrigation and water availability.

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, with a full range of possible intermediary crops in between. Physical configurations of terrains (vast plains, narrow plains, basins, slopes, etc.) determine the possibilities for automation or mechanization, industrial and semi-industrial exploitation (CDR, 2005).

Almost half of Lebanon's total surface area could be cultivated, although with different levels of productivity. The country's "real" arable land resides in large areas, representing altogether around one third of its total land mass (CDR, 2005).

The main crop production regions are distributed as follows (Saade, 1994):

- **The coastal strip,** where the main cultivated crops are citrus fruits, bananas, horticulture products and vegetables which are predominantly grown in plastic greenhouses.
- **The Akkar plains**, including the lower slopes of northern Mount Lebanon, where cereals, potatoes, grapes and vegetables are grown.
- **The central Bekaa valley** where potatoes, vegetables, grapevine, stone fruits and grains are mainly cultivated.
- **The mountainous region**, which is characterized by its steep valleys terraces where fruit orchards and vegetables are grown.
- The western slopes of the Mount Hermon and Anti-Lebanon range, where grapes, olive and cherry are the dominant crops.
- **The hills in the South** where olives, grains, tobacco and almonds are primarily produced.

Agricultural production is concentrated in the Bekaa valley, which accounted for 42 percent of total cultivated land in 2005 (Figure 2-2) and the highest percentages of essential crop types such as cereals and vegetables (Figure 2-3).

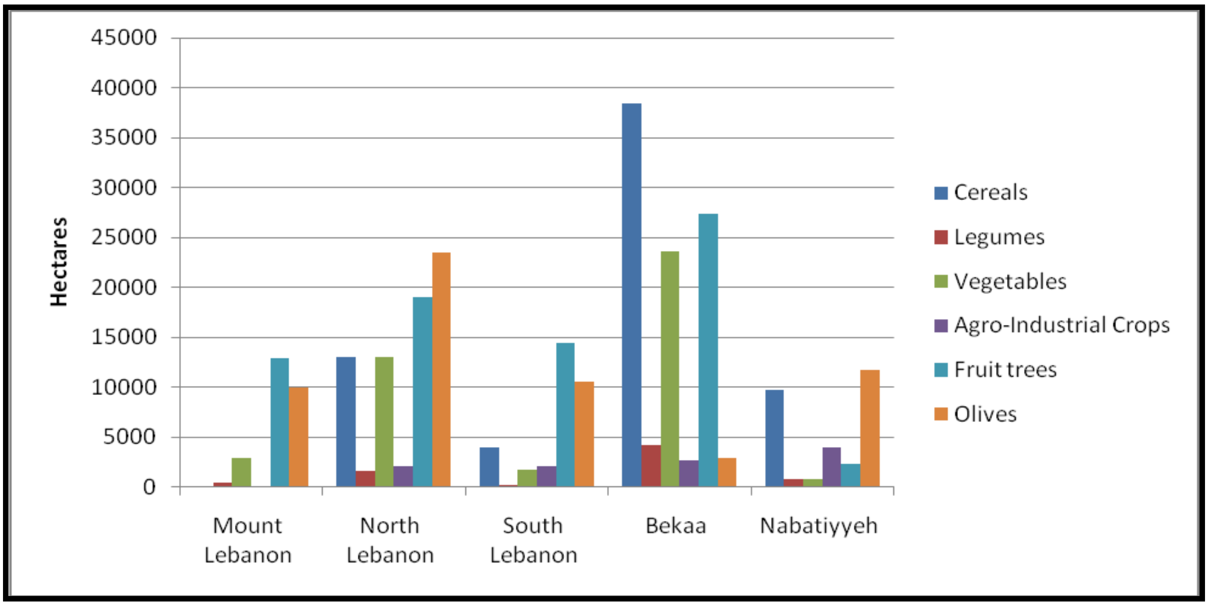

Figure 2-2 Distribution of crop area by governorate

Source: MoA, 2007

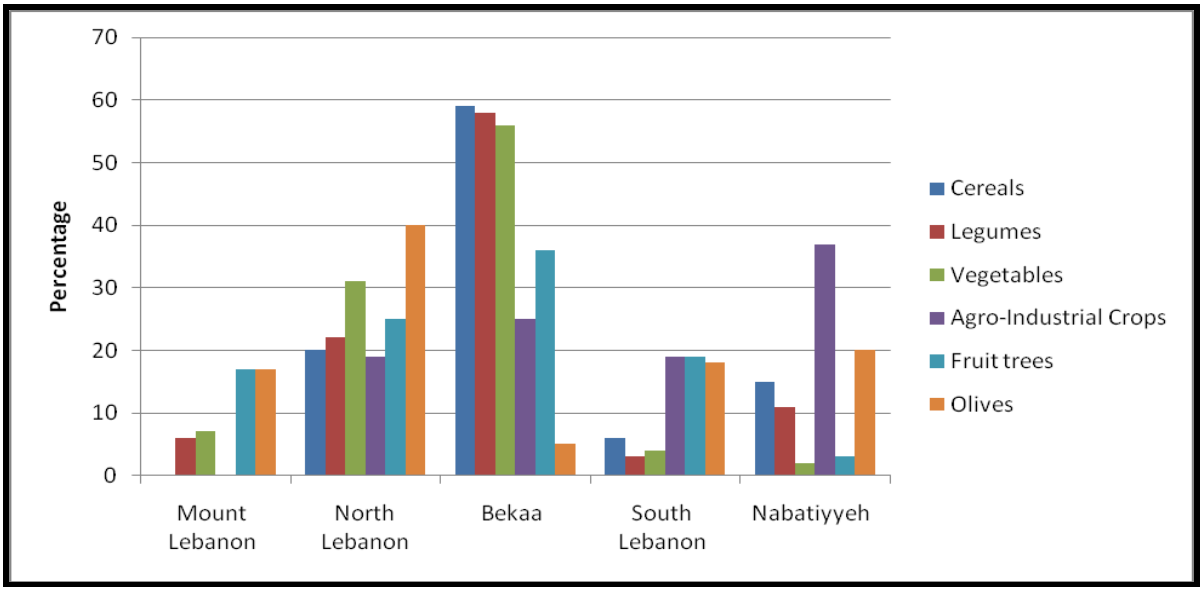

Figure 2-3 Percentage distribution of crops grown by governorate

Source: MoA, 2007

Cereals

The most important cereals cultivated are wheat, barley and corn (MoA, 2007). Cereal production is essential for food self-sufficiency. In 2005, cereals were the second most-widely grown crop type, occupying 65.2 thousand hectares or 23.8% of the total cultivated area (MoA, 2007). Production reached 394.4 thousand tonnes in 2005 with a total value of 92.9 billion LBP (MoA, 2007). Durum wheat is the most widely grown cereal crop type (49.5 thousand hectares in 2005) (Figure 2-4), producing 143,700 tonnes valued at 60% of the total value of cereal production. It is followed by barley (14.5 thousand hectares in 2005) and corn (900 hectares in 2005) (FAO, 2009).

Lebanon is a net importer of wheat, with import value reaching 201 billion LBP in 2005 (MoA, 2007). The price of imported wheat is much lower than the farm gate price of locally-grown wheat (MoA, 2007). The State supports wheat cultivation as a strategic crop for food security, and to maintain the value of rainfed arable land. Although local durum wheat is not suitable for bread production, it remains the only type of wheat cultivated in Lebanon, and is used in the local food industry (borghul, freek, kishek, pasta, etc). Since wheat is largely a rainfed crop (54% of cereals are non-irrigated crops), its yields vary with the amount of rainfall. The yield has been increasing on the overall, especially due to the introduction of irrigation. The yield for wheat reached 2.9 tonnes/ha in 2005 (Figure 2-4). Barley is mostly cultivated as animal fodder.

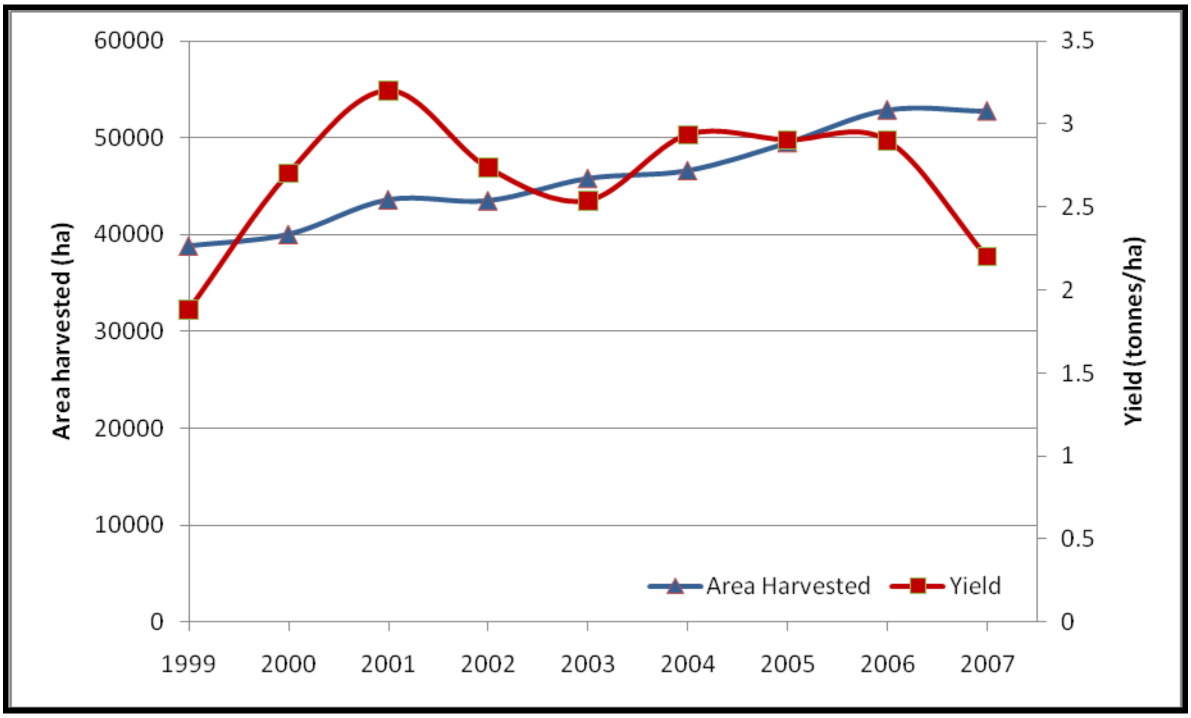

Figure 2-4 Cultivated area and yield of wheat

Source: FAO, 2009

Vegetables

These are usually divided into leafy vegetables such as artichokes, cauliflowers, cabbages, lettuce and salad greens; tuber vegetables such as potato and carrot; and fruit-bearing vegetables such as peppers, cucumbers, eggplants, tomatoes, melons and watermelons. Potato constituted almost half of the total vegetable cultivation in 2005, covering 19.7 thousand hectares (or 46.8% of vegetable-cultivated area) and 7.2% of the total cultivated area (Figure 2-5). Potato is an essential crop that is important for food security, in terms of consumption and food trade because Lebanon is a net exporter of potato (Figure 2-6).

Tomato is the second most-widely grown vegetable crop, covering 8.8% of the vegetable-cultivated area. Despite the decrease in the harvested area of tomato, the yield has been increasing, mainly due to the use of good quality seeds and mechanization in tomato cropping and harvesting (Figure 2-7). Lebanon is a net importer of tomato (Figure 2-8).

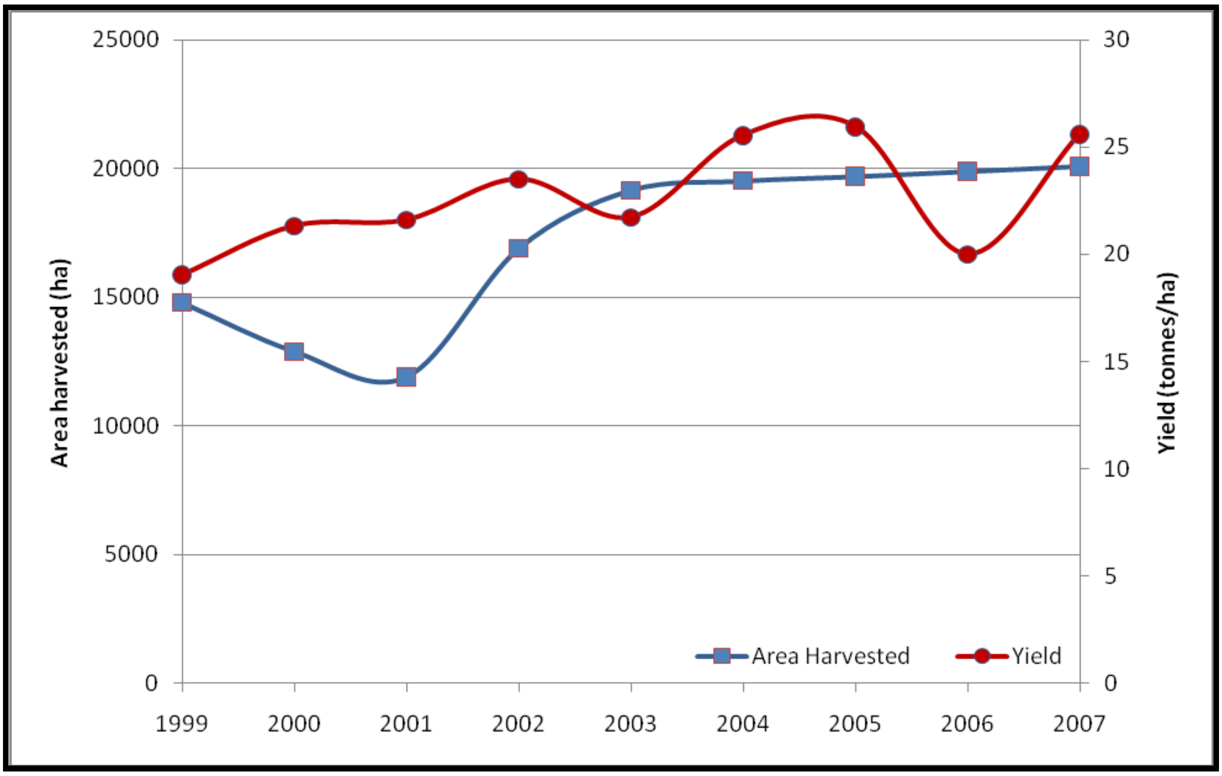

Figure 2-5 Cultivated area and yield of potato

Source: FAO, 2009

Figure 2-6 Potato import and export quantities and value

Source: FAO, 2009

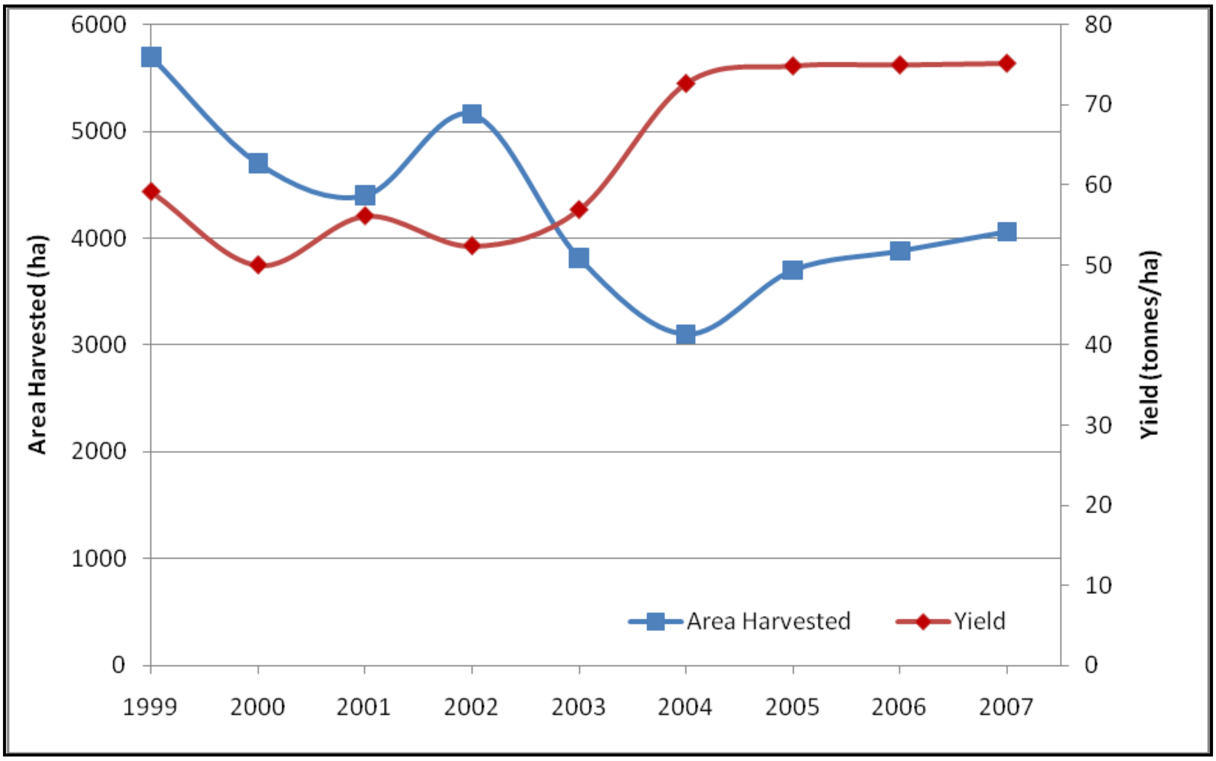

Figure 2-7 Cultivated area and yield of tomato

Source: FAO, 2009

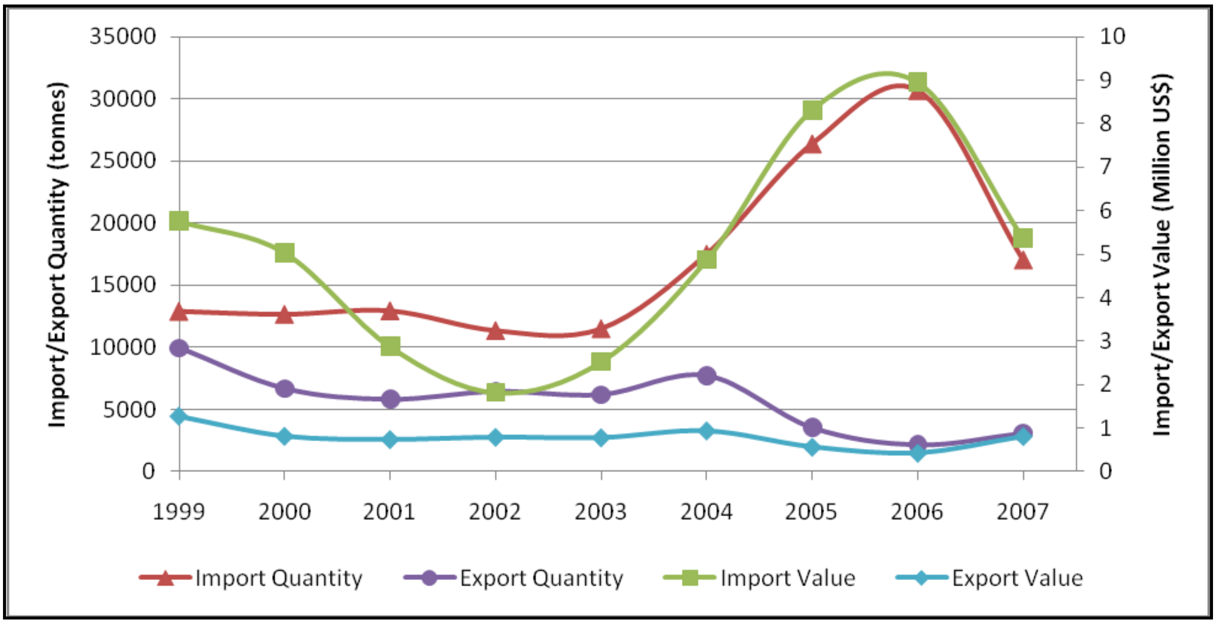

Figure 2-8 Tomato import and export quantities and value

Source: FAO, 2009

Fruit Trees

These include citrus, pome fruits, stone fruits, tropical fruits including, carobs, almonds and nuts. Fruit cultivation is one of the most important elements of agricultural income with 40% of total crop production quantity (in 2005) (MoA, 2007), 36.5% of the agricultural value-added (in 2005) (MoA, 2007) and 28% of the total productive agricultural area (FAO, 2009, MoA, 2007) (Figure 2-9, Figure 2-10). Fruit trees cultivation is concentrated in the Bekaa (36%), followed by North Lebanon (25%), South Lebanon (19%), Mount Lebanon (17%) and Nabatiyyeh (3%) (MoA, 2007).

Fruit trees include the fourth most widely-grown: cherries (Figure 2-11), after grapes (Figure 2-12), oranges and apples (Figure 2-13), and the 11th most-widely grown: bananas (Figure 2-14). The largest exportable crops by quantity and value are citrus fruits, apples, bananas and grapes (FAO, 2009). Cherries are the ninth largest fruit export by quantity and the sixth largest by value (FAO, 2009). Lebanon is a net regional exporter of oranges, apples (Figure 2-15), bananas (Figure 2-16), grapes (Figure 2-17) and cherries (FAO, 2009), thus maintaining a positive trade balance in fresh fruit products. It is worthwhile noting that 99% of the banana export is received by Syria (MoA, 2007). Lebanon grows grapes as an industrial crop for wine making. The local wine industry produces one of the major agricultural exports by value (US$ 10.4 million in 2005) (FAO, 2009) (Figure 2-18).

Although olive trees are technically fruit-bearing trees, the agricultural census of Lebanon considers this crop in a stand-alone category due to its local economic importance. Olives are the single largest crop by total surface area, grown over 21.5% of the total productive agricultural areas, or 58.8 thousand hectares, in 2005 (MoA, 2007). Olives are largely non-irrigated (MoA, 2007). The North Lebanon governorate retains the largest production areas (40%), followed by Nabatiyeh (20%), South Lebanon (18%), Mount Lebanon (17%) and Bekaa (5%) (MoA, 2007). Olive fruit bearing is not consistent across the years; in 2004, the production reached 167,000 tonnes while it reached 76,500 tonnes in 2005 (MoA, 2007) (

Figure 2-19). Olive oil is rapidly becoming an important export commodity; Lebanon exported 29% of its production of olive oil in 2005 (FAO, 2009). However, it must be noted that not all of the production is from locally-grown crops. In the same token, imports of virgin olive oil are rapidly increasing due to the removal of trade barriers between Lebanon and the EU – the major olive-oil producing region in the world.

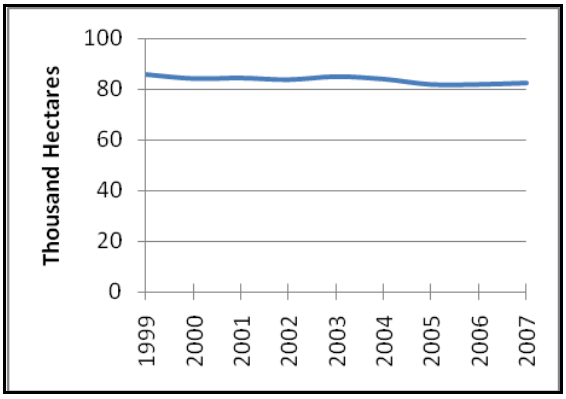

Figure 2-9 Fruit trees cultivated area

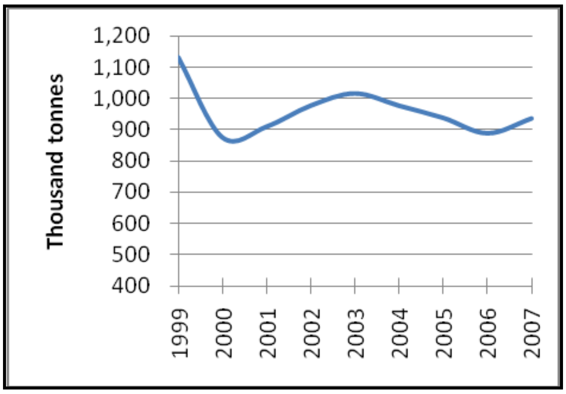

Figure 2-10 Amount of fruit trees production

Source: FAO, 2009

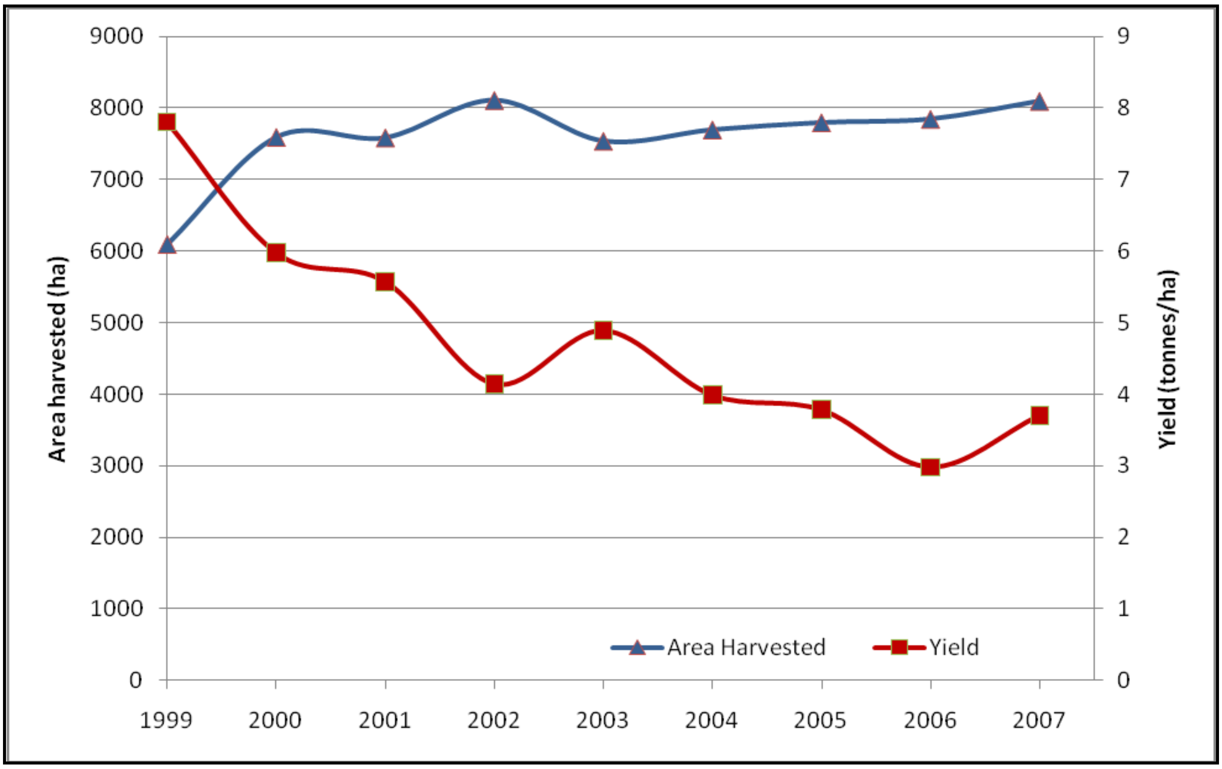

Figure 2-11 Cultivated area and yield of cherries

Source: FAO, 2009

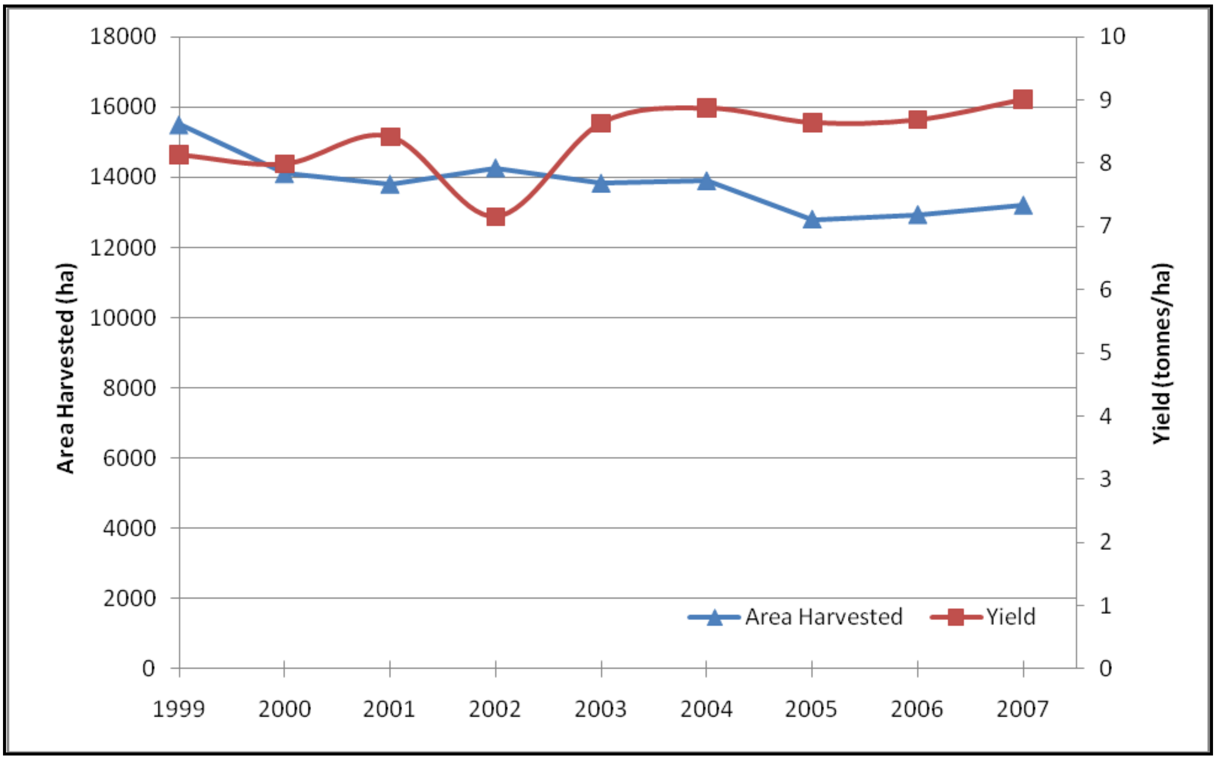

Figure 2-12 Cultivated area and yield of grapes

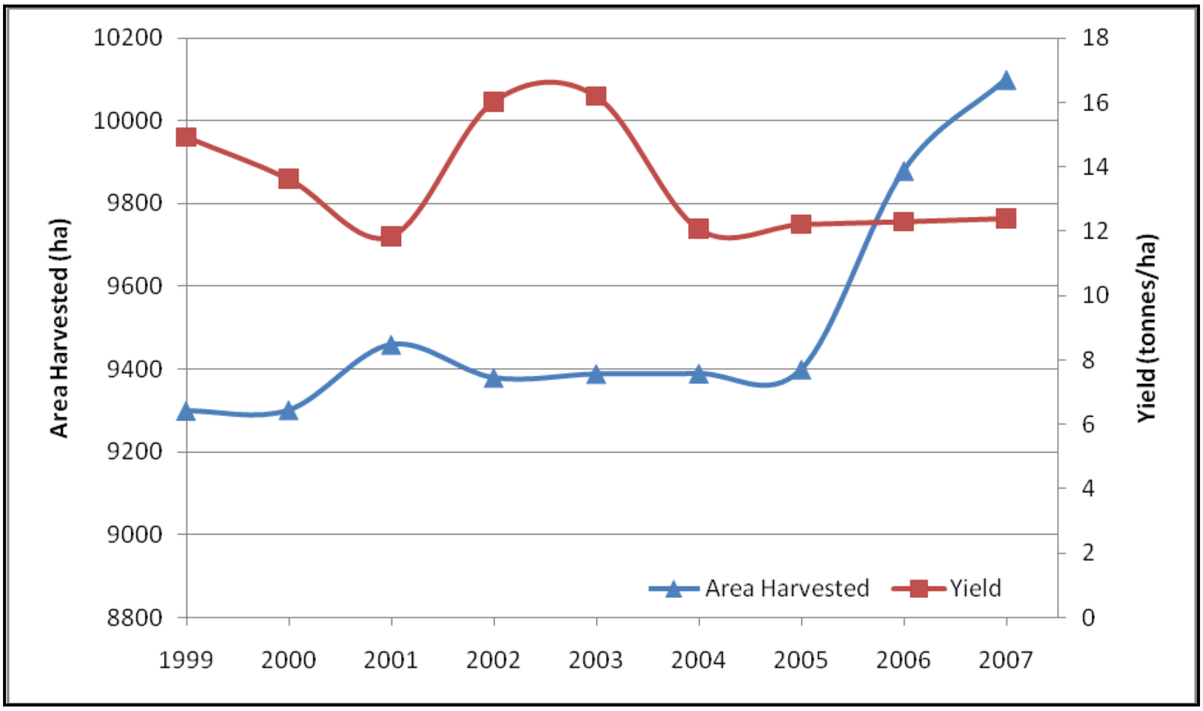

Figure 2-13 Cultivated area and yield of apples

Source: FAO, 2009

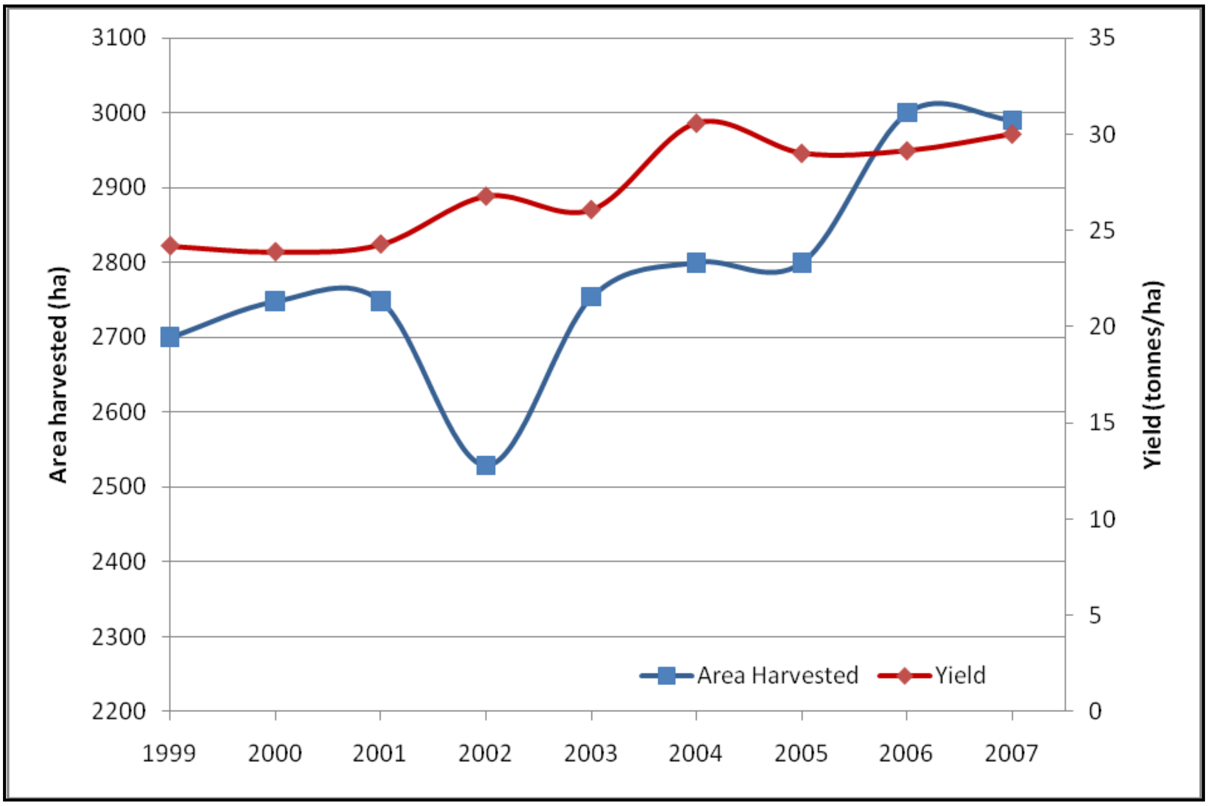

Figure 2-14 Cultivated area and yield of banana

Source: FAO, 2009

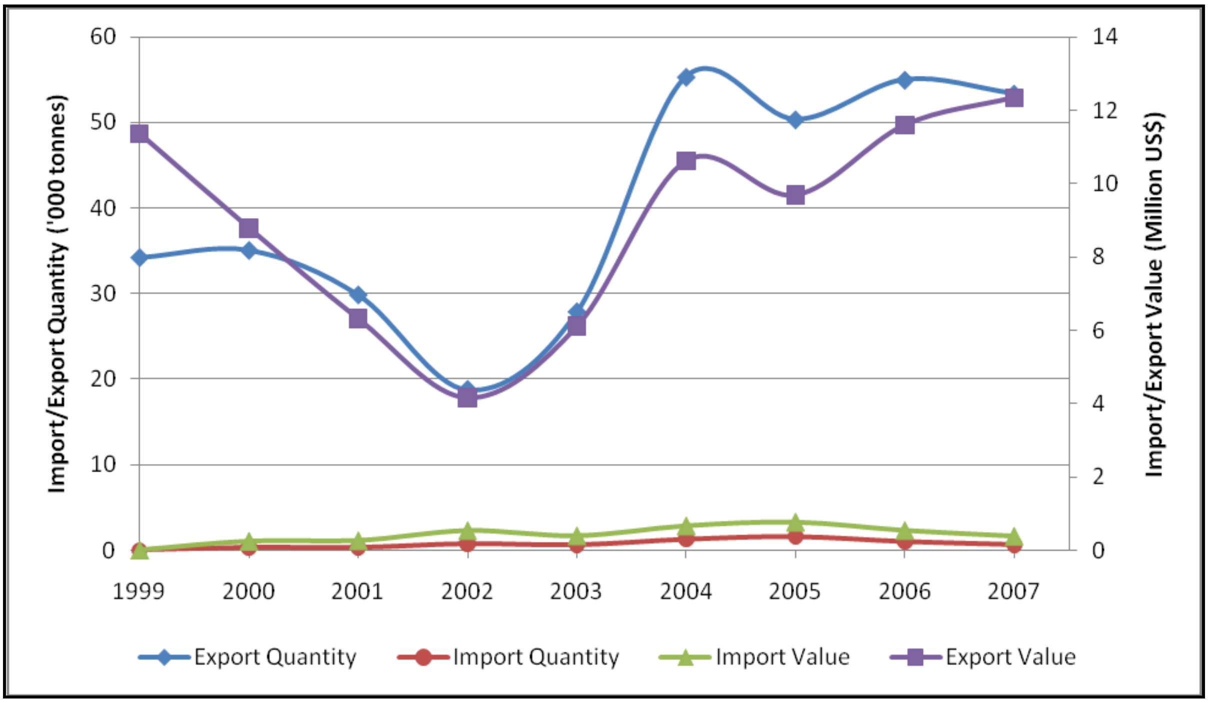

Figure 2-15 Apple import and export quantities and value

Source: FAO, 2009

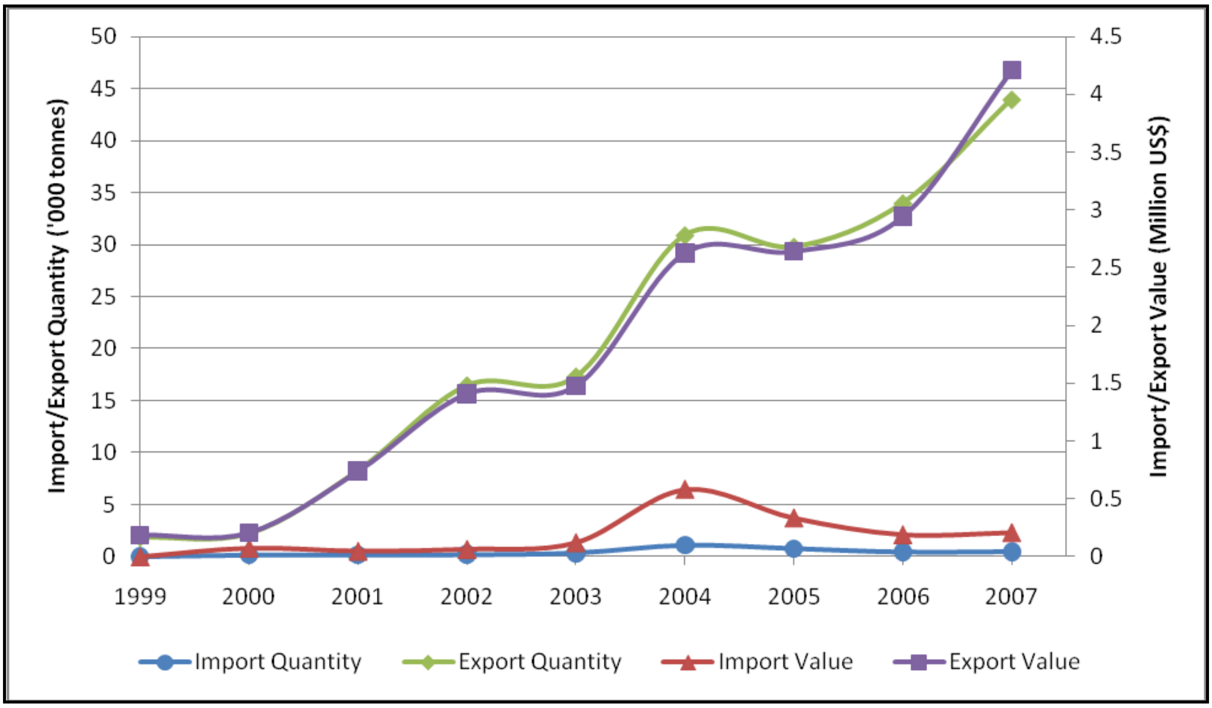

Figure 2-16 Banana import and export quantities and value

Source: FAO, 2009

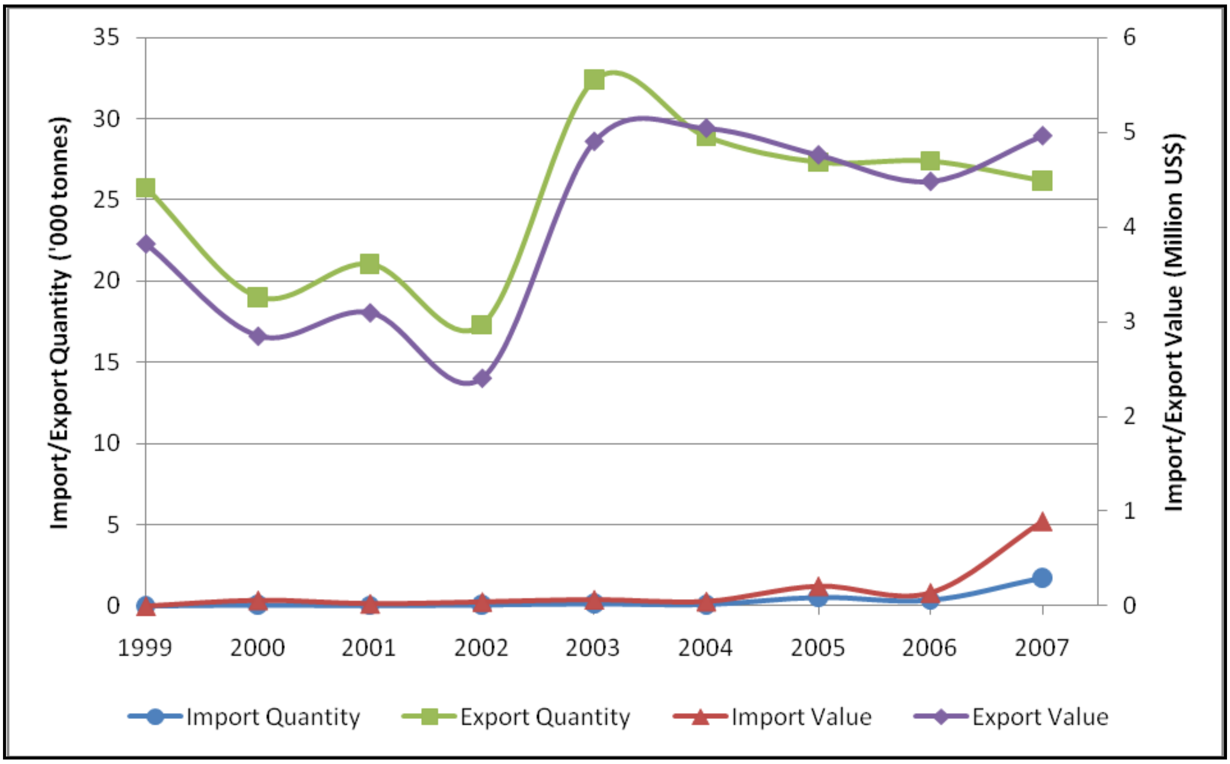

Figure 2-17 Grape import and export quantities and value

Source: FAO, 2009

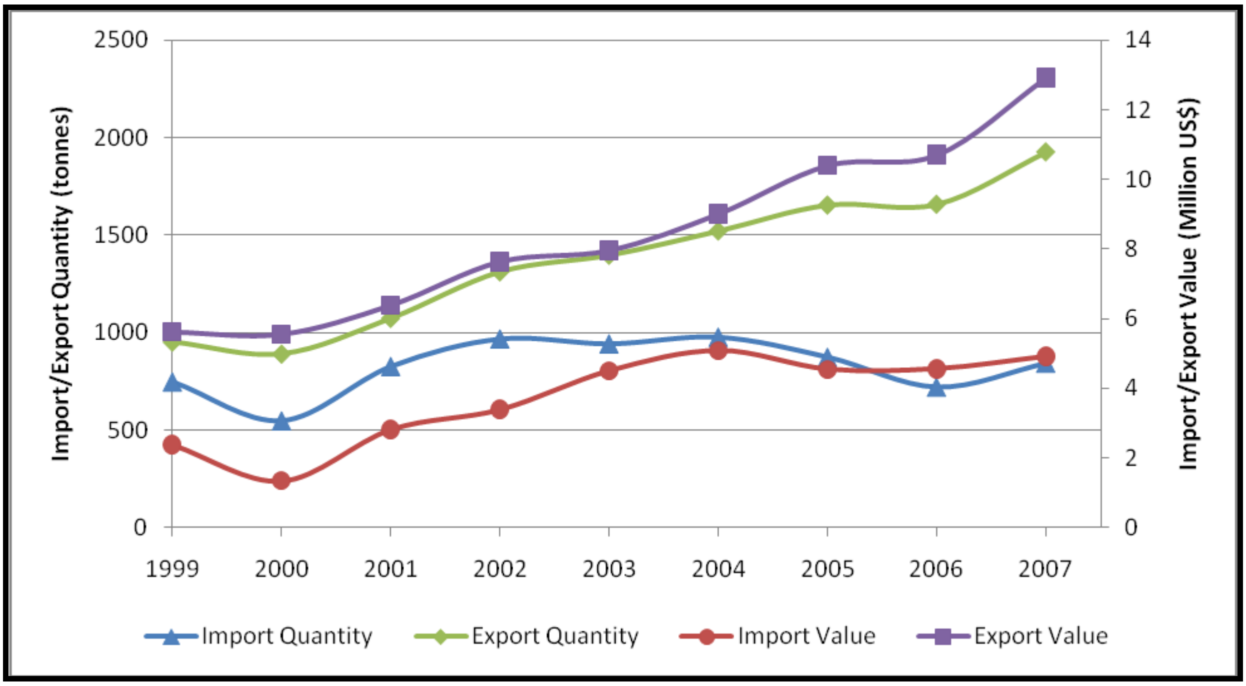

Figure 2-18 Wine import and export quantities and value

Source: FAO, 2009

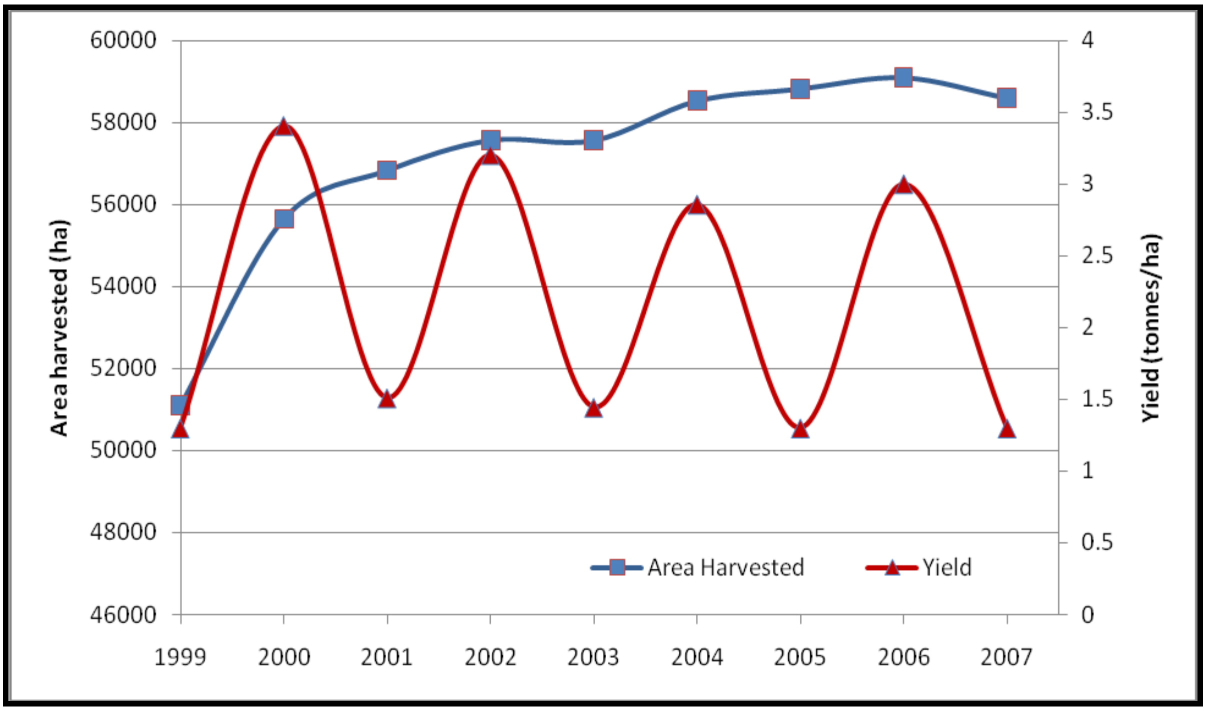

Figure 2-19 Cultivated area and yield of olive trees

Source: FAO, 2009

Animal Production Components

The livestock sector in Lebanon faces difficulties on the levels of production and marketing.

Main livestock products include red meat of different varieties, poultry meat, in addition to milk and its derivatives, eggs, honey and fish. The quantities produced meet a small part of the local consumption demand. Consequently, the country relies on the import of animal products to meet the overall consumption demand. The exception, however, is the poultry sector where national poultry meat and egg production meet the overall demand for these products. Small ruminants include goat and sheep and constitute the largest livestock number (by stock heads) (Figure 2-20). In 2005, the MoA's agricultural census reported the presence of 337,000 heads of sheep and 495,000 heads of goats (MoA, 2007). Most of the herds are found in the Bekaa governorate, followed by North Lebanon (Figure 2-21) (MoA, 2007).

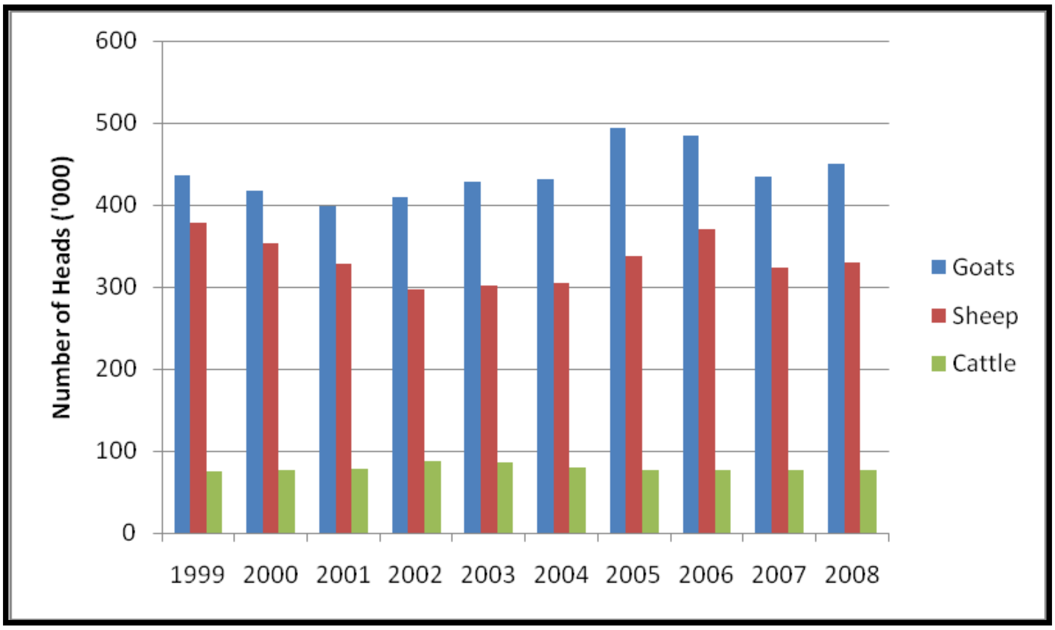

Figure 2-20 Number of livestock heads by type

Source: FAO, 2009

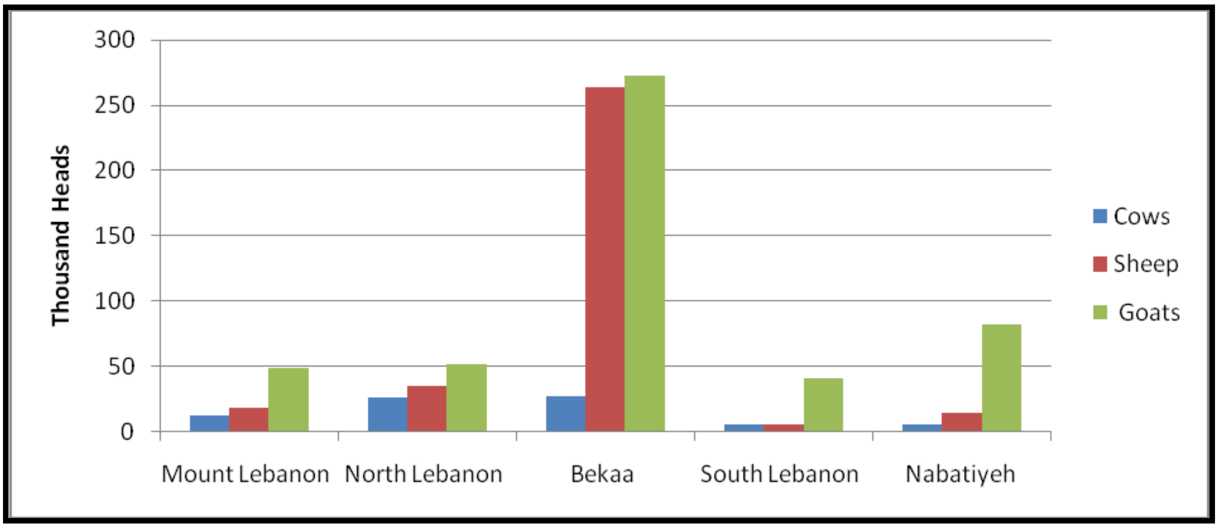

Figure 2-21 Number of livestock by governorate

Source: MoA, 2007

Red Meat production

Livestock production is an important activity, particularly in the mountains and in the Baalbeck-Hermel area on the eastern mountain chain where soil fertility is relatively low. The number of goats has been relatively stable for more than two decades, whereas sheep production has risen sharply. In recent years, livestock production, especially goats and sheep, has increasingly relied on feed blocks and feed supplements, thereby reducing dependence on wild grazing and ultimately leading to more sedentary animal production (MoE, 2001). Sheep produced 5,400 tonnes of live animals for meat, while goats' production was 6,600 tonnes (MoA, 2007). Goat meat supply meets the local consumption needs; however, Lebanon imports 65% of the sheep meat consumed. In general, the country is a net importer of dairy products as well (MoA/FAO 2005a).

Milk and dairy products

The local milk production meets more than one-third of Lebanon's consumption needs (in fresh milk equivalent), including butter and cheese of different kinds (MoA, 2007). The largest amount of milk is produced from farms in the Bekaa region (Figure 2-22).

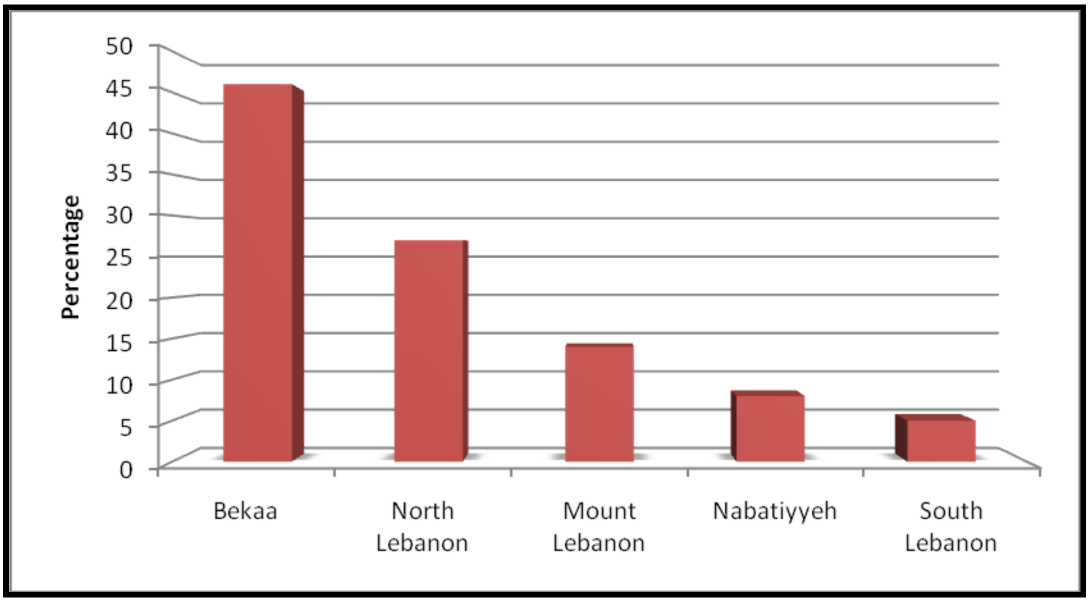

Figure 2-22 Milk production by governorate

Source: MoA, 2007

Cow milk represented 75 percent of the total quantity of milk produced in 2005, while goat and sheep milk represent 16 percent and 9 percent respectively (Figure 2-23). In 2005, sheep and goats produced 23,000 tonnes and 39,000 tonnes of milk respectively, or 25% of the local milk production (Figure 2-23).

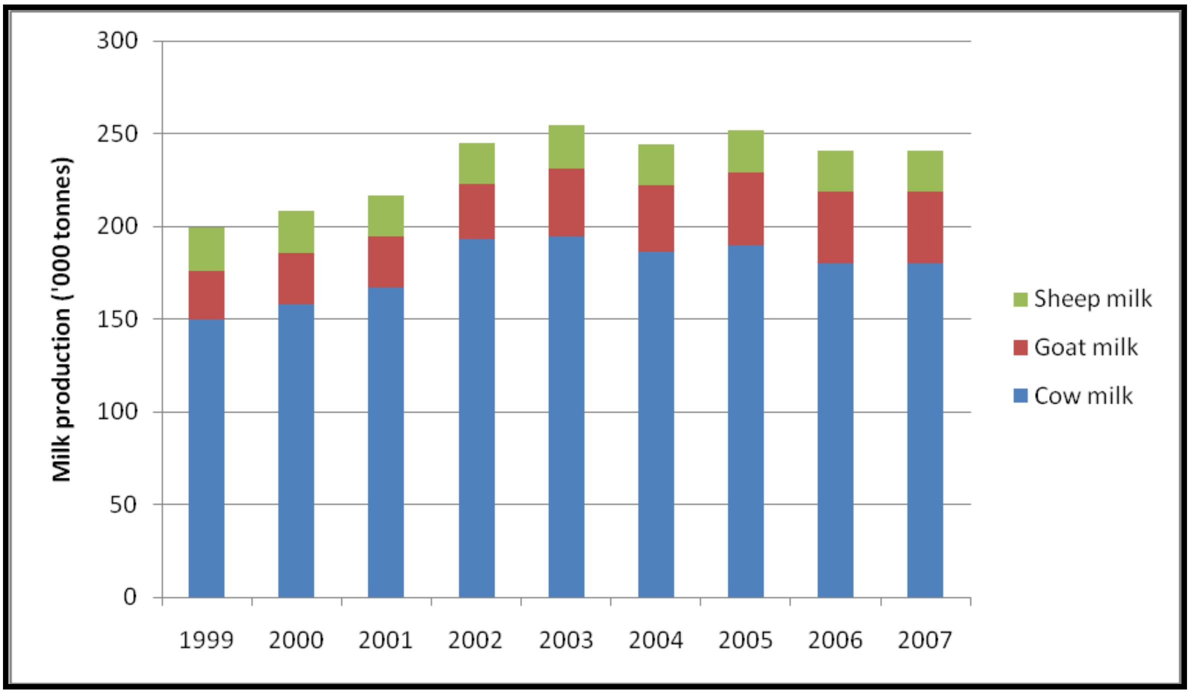

Figure 2-23 Milk production by livestock

Source: FAO, 2009

Irrigation

In Lebanon, agriculture is the most water-demanding sector (about 70% of water resources). However, it adds the least value to the economy (an average of 5.8% between 1999 and 2007). Irrigation was applied in 50% of all agricultural areas in 2005 (MoA, 2007) (Figure 2-24) making them more susceptible to any decrease in water supply.

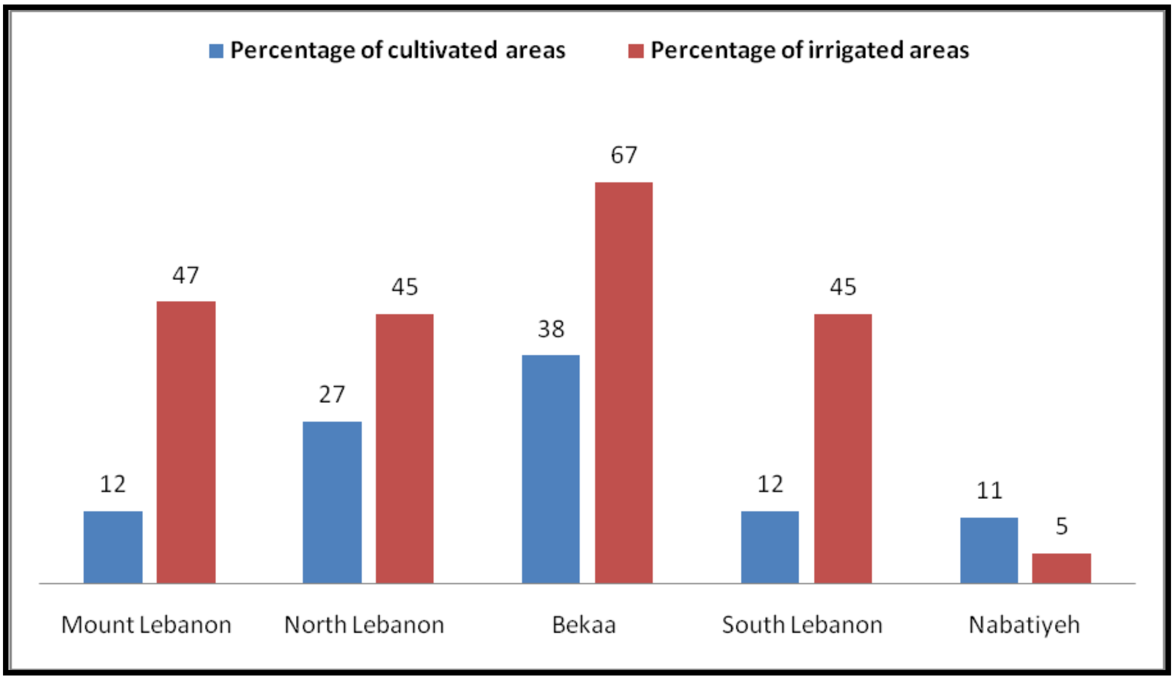

Figure 2-24 Percent of cultivated versus irrigated areas by governorate

Source: MoA, 2007

The majority of irrigation techniques are gravity (or surface) irrigation (57.2% of all irrigated lands) – especially when surface water is used for irrigation (Figure 2-25). Localized irrigation, including drip techniques, represent 7.7% of all irrigated lands in 2000 (FAO, 2010). It is generally noted that sprinkler and drip irrigation are more commonly used when irrigation relies on groundwater and for specific crops such as potato, sugar beet and cereals. In 2000, the proportion of agricultural water withdrawal out of total water withdrawal was estimated at 66.67%; it decreased to 59.54% in 2005 (FAO, 2010). The majority of irrigated lands use surface water sources (44.4%), while 22.2% use groundwater and the remaining 30,000 hectares of irrigated agricultural areas use mixed sources (FAO, 2010).

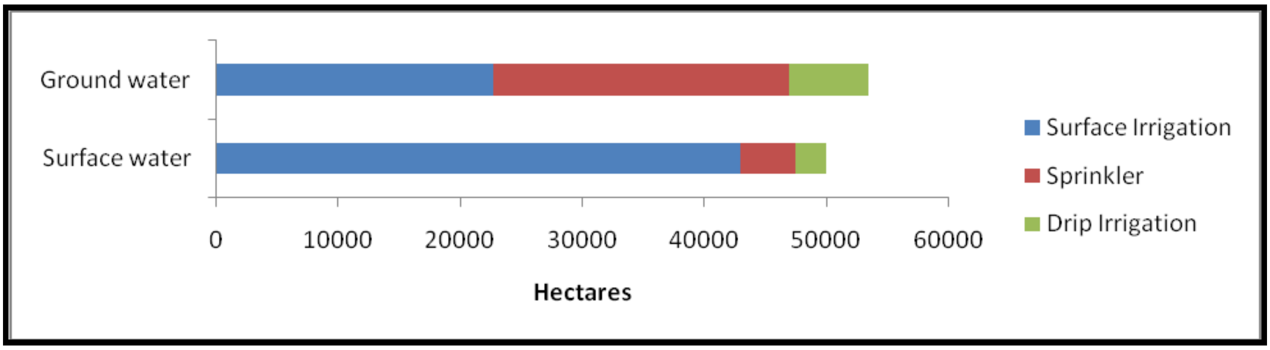

Figure 2-25 Distribution of irrigated lands by source and irrigation technique used

Source: MoA/FAO, 2000 in MoE, 2001

Contribution of Agriculture to the Economy

Between 1999 and 2007, the agriculture sector's share of GDP averaged 5.8% of the total value-added (Figure 2-26). Employment in the agriculture sector has been steadily declining, where in 2005 only 2.5% of the total economically active population was employed in agriculture (Figure 2-27).

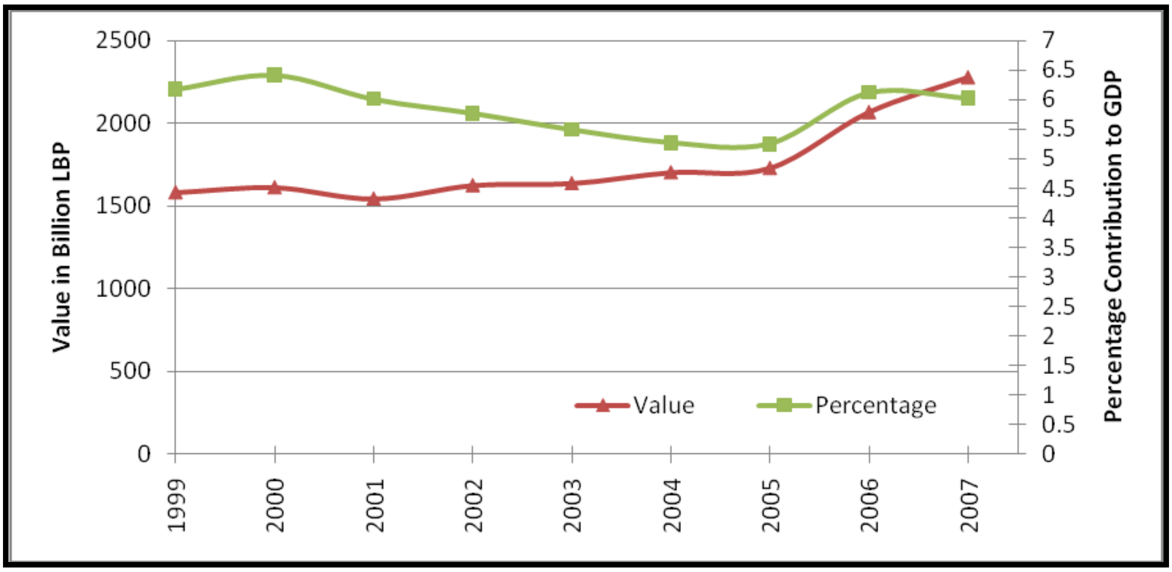

Figure 2-26 Contribution of agriculture to GDP

Source: EAM-PCM, 2005, 2006, 2007a, 2007b, 2009

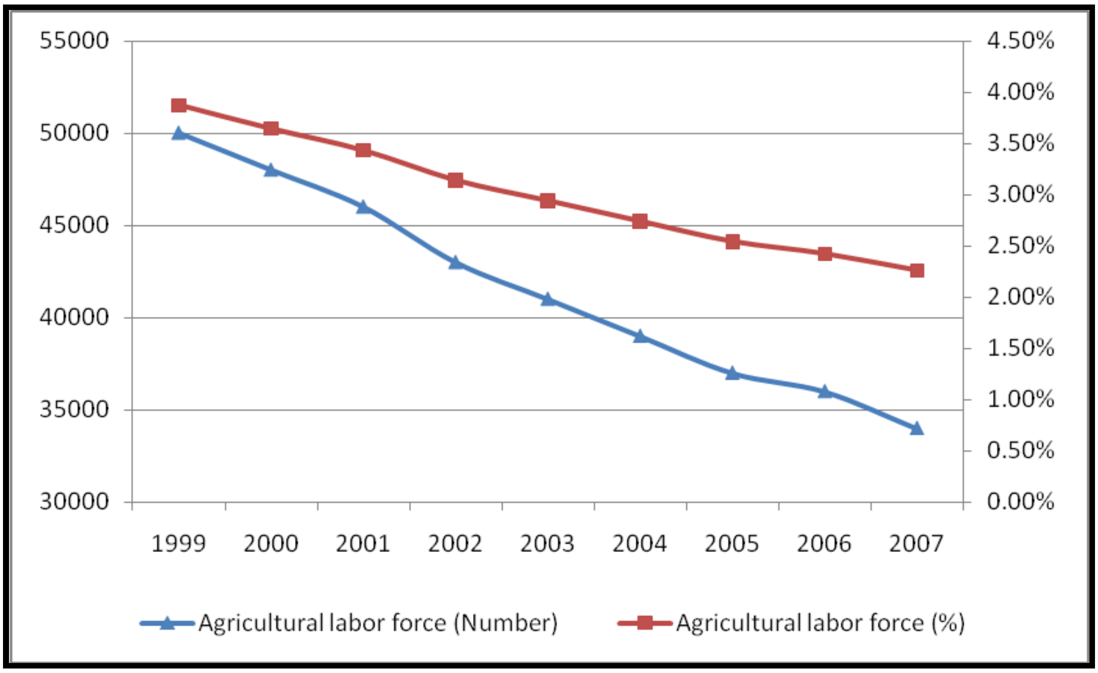

Figure 2-27 Number of population employed in agriculture and their percentage of the total labor force

Source: FAO, 2010

Despite all the potential of the agricultural sector due to temperature and rainfall variations over the Lebanese territories, private investment and state support to the sector are insufficient for the sector to realize its full potential. Under-investment in the agricultural sector has contributed to retraction in its contribution to the national economy and a lack of interest from investors and the young workforce. Another issue which is influencing the decrease in productive lands is the decrease in the average plot size due to inheritance laws, thus rendering agricultural exploitation unprofitable. Only 1% to 3% of the annual public budget is allocated to agriculture services. Investments in this sector are mostly sourced from the private sector, FAO grants and bi-lateral aid.

Relationship between population growth and agriculture

Commensurate with the decrease in the total agricultural labor force, the agricultural population and its density are also on a decreasing trend. The average annual decrease in the agricultural population between 1999 and 2007 has been estimated at 5.4% (FAO, 2010). The agricultural population density, measured the agricultural population per hectare of arable and permanent crops, has decreased from 0.7 in 1990-1992 to 0.3 in 2003-2005, despite a decrease in the area of arable and permanent cropland by 7.2% between 1990 and 2005 (FAO, 2010).

The North, Akkar, Bekaa and Baalbeck-Hermel governorates will witness the highest population growth rates by the year 2030 (CDR, 2005) (Figure 2-28). Coincidently, these governorates are the site of the largest agricultural areas in the country.

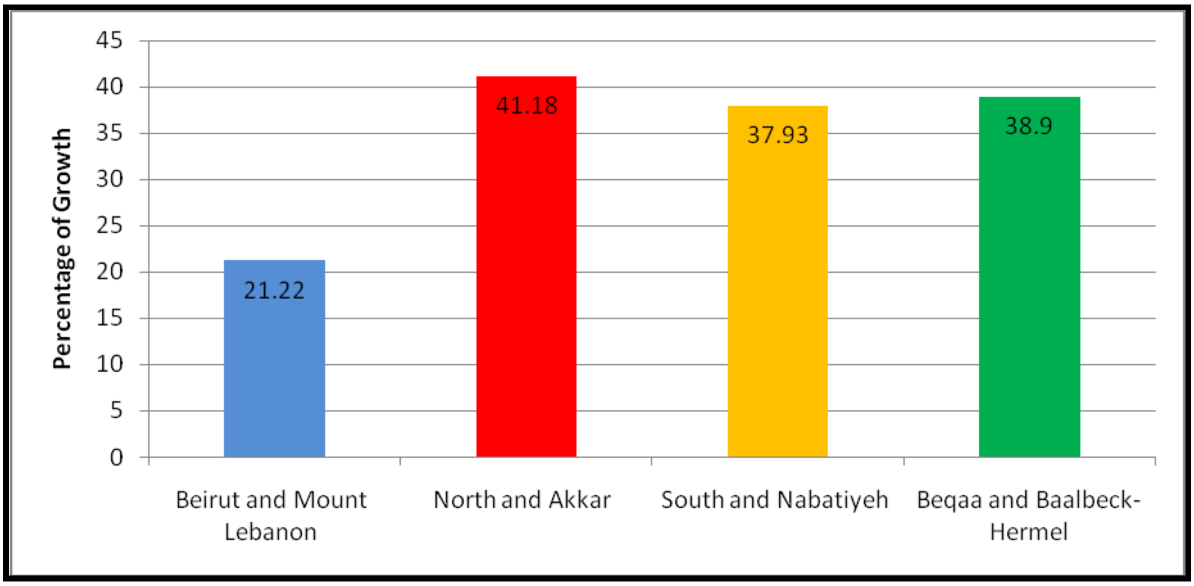

Figure 2-28 Population growth from 1997 to 2030

Consequently, population growth in these areas will affect the agriculture sector in three main ways:

Population growth demands expanded residential areas which will encroach onto agricultural lands, especially when 85% of the agricultural lands are privately owned (MoA/FAO 2000 in MoE, 2001) and land use designations are poorly adhered to. The urban pressure on agricultural lands can be clearly seen in Figure 2-29. Converting agricultural fields to built-up, residential or commercial districts provides a faster return on investment to land owners as land values and prices increase, especially on the coast and in peri-urban areas.

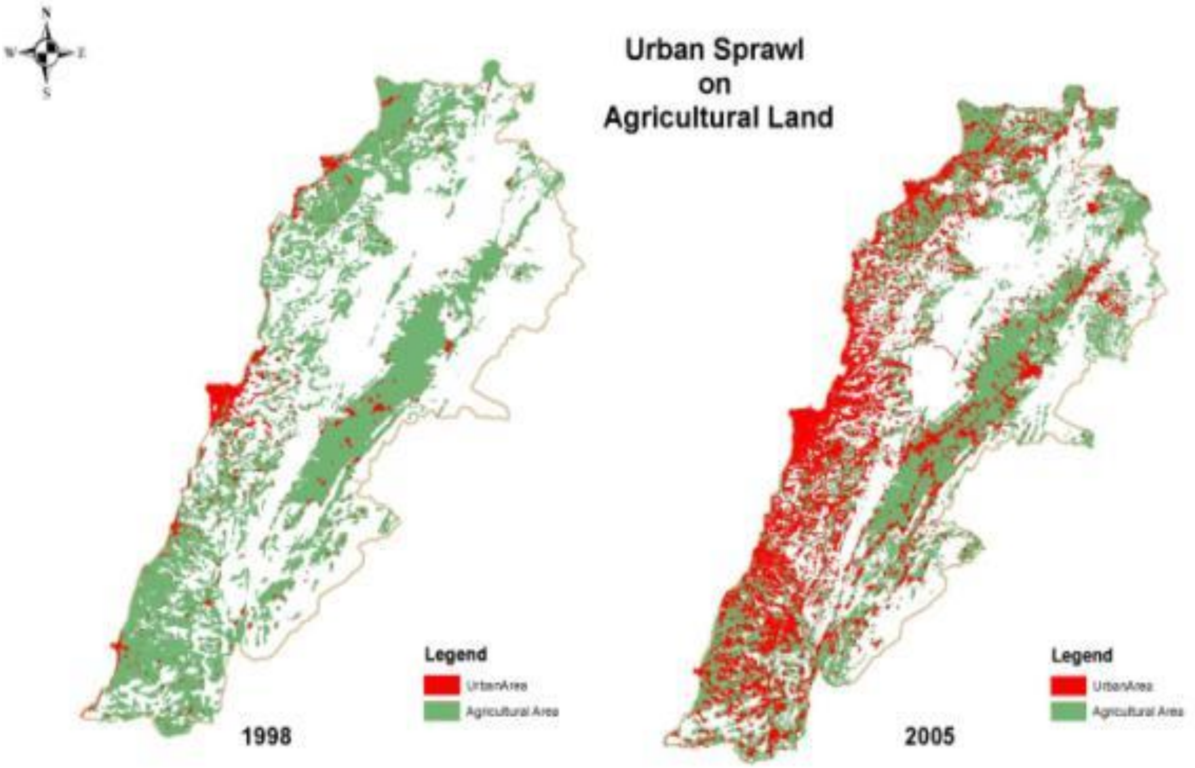

Figure 2-29 Urban sprawl between 1998 and 2005

Source: CDR, 2005

- Population growth exerts more pressure on agricultural production where the higher demand for food might lead to more intensive agricultural practices that are characterized by the excessive use of fertilizers and increase in the use of water for irrigation. Gradually, with increasing wealth it is likely that increasing food demand due to population growth and increased per capita demand will be increasingly met from imports.
- Population growth will lead to a higher demand on water for domestic use. The CDR's 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. 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 in water withdrawals 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 (Table 2-1). The total need is estimated at 1,410 Mm^3 in 2030, versus 1,600 Mm^3 estimated by CDR (2005). The projections appearing in Table 2-1 were based on an assumption of 100,000 ha of irrigated surface area in 2000. However, the actual irrigated areas grew at a slower rate, and totaled 136,000 ha in 2005 (MoA, 2007), 15% less than the estimated figure for 2030.

Table 2-1 Projections of water demand by the agriculture sector

YEAR	2005	2010	2015	2020	2025	2030
Irrigated Surface Area (1,000 ha)	160	190	145	190	212	235
Total (Mm^3/Year)	1,280	1,140	1,450	1,140	1,272	1,410

Source: Hreiche, 2009

Food Security

OLIVE OIL AS A MAJOR SOURCE OF FAT INTAKE

Between 1999 and 2007, Lebanon produced an annual average of 6,100 tonnes of virgin olive oil (FAO, 2009). The country maintains a positive trade balance in virgin olive oil and production meets the consumption needs of the resident population (FAO, 2009). Nevertheless, the overall vegetable oil consumption is largely deficient in Lebanon.

POTATO AND WHEAT AS MAJOR SOURCES OF CARBOHYDRATE INTAKE

Lebanese production of potatoes meets the local consumption needs. Imports are limited to basic material for seeding and few months where the local production is lacking as well. Exports occur in months with excess production. Potato is largely consumed by the local population and is essential in the Lebanese diet. The overall production is meeting the increasing local demand, while maintaining a certain share for export (Figure 2-6).

On the other hand, the cultivated durum wheat is only used as bulgur wheat (locally known as borghul) and for pasta making. Bread, an essential staple food product, relies totally on imported wheat for its production. Nevertheless, wheat production's share in the local food supply increased from 16% to 30% between 1999 and 2005 (FAO, 2009).

MILK AND MEAT AS MAJOR SOURCES OF PROTEIN INTAKE

Milk production has been steadily rising in Lebanon. The share of small ruminants in total milk production is about 33% (Figure 2-23). Imports of fresh milks have been diminishing since 1999; while exports, which were nil, have started to rise modestly since 2004 (FAO, 2009). Lebanon ensures more than one-third of its demand of milk and dairy products from local sources (MoA, 2007).

Lebanon does not meet more than 15% of its demand of red meat (MoA, 2007) with the exception of goat meat, although its local consumption is modest. Mutton and beef imports have been increasing since 1999 (FAO, 2009). On the other hand, poultry meat production has increased to ensure the local food consumption and show some exports (FAO, 2009).

2.1.2. Methodology

2.1.2.1. Scope of Assessment

Unit of Study

The criteria of selection for the vulnerability assessment focused on crops that are of economic importance (Table 2-2), in addition to livestock and crops that are totally dependent on the amount of rainfall such as grazing small ruminants, rainfed crops (olives, grapes and wheat) and crops whose production is highly vulnerable to temperature changes (stone and pome fruits).

Crops that require a large initial investment and have long payback periods, such as perennial crops, are prioritized. Water demanding crops, such as bananas, tomatoes and potatoes were 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.

Spatial frame

The assessment covers the entire country with focus on the areas where the target crops and fruit trees are produced.

Temporal frame

The impact of climate change can be assessed 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.

Finally, a period of 25 years with 2005 as baseline year is adopted for the analysis of vulnerability.

Table 2-2 Criteria of selection of agricultural crops and sub-sectors

CRITERIA	AGRICULTURE CROPS AND SUB-SECTORS								
	Temperate fruit trees (e.g. apple, cherry, almond, olive…)	Irrigated horticulture (e.g. potato, tomato)	Citrus crops	Rainfed cereals and legumes	Banana	Cattle and poultry	Small ruminants	Fisheries	Beekeeping
Impacts from climate variations	3	2	1	3	1	1	3	2	3
Economic importance	3	3	3	2	3	3	2	1	2
Number of farmers	3	3	2	2	2	2	2	1	1
Resources needed to adapt to climate change	3	2	1	1	2	1	2	1	1
Total	12	10	7	8	8	7	9	5	7

Values from 1 to 3 indicate an ascending degree of importance. Sub-sectors with scores above 7 are selected for vulnerability assessment.

2.1.2.2. Climate factors

The PRECIS Model delivered the climatic data required to assess the impact of climate change for the near (2025-2044) and far (2080-2098) future.

Climatic parameters that were found pertinent to assess the impact of climate change in the agriculture sector were the following: Tmax, Tmin, rainfall amount, rain patterns, relative humidity, and transpiration or evaporation.

Tmax: An increase in temperatures above 30 or 40˚C (depending on the crop) during the vegetation period would hamper the growth of many annual crops; inhibiting blossoms, reducing photosynthesis and reducing yields. In perennial crops, high temperatures would reduce yields if water needs are not satisfied, and could cause burns on fruit skins if accompanied by strong sun radiation. Higher Tmax means higher evapotranspiration and higher water demand.

Tmin: Minimal temperature is necessary to calculate the chilling requirement of fruit crops in order to ensure full blossom at a later stage. Chilling requirement is the cumulative number of hours where temperature is between 0˚C and 7.2˚C during the winter period (from November to the end of March) when vegetation is relatively dormant until buds burst. Since it is very difficult to generate climatic data on an hourly basis, it was estimated that the daily Tmin would be valid for at least six hours (ongoing thesis with Balamand University and Cyprus Institute for hourly simulation of temperature). Thus, the product of six hours by the number of days with Tmin between 0˚C and 7.2˚C yielded the number of hours with chilling temperatures. Tmin is also essential to see if optimal conditions are ensured for winter crops, like wheat and winter vegetables. Frost conditions are also taken into account in winter and spring.

Rain patterns: meaning the number of rainy days and rainfall distribution during the vegetation period, are essential especially for rainfed crops and grasslands. A minimum of 4mm per day is necessary, since below that, rainfall is lost to evaporation and surface runoff. Data is analyzed on a monthly basis. Rainfall intensity is also taken into account. A large amount of rainfall per day could damage several crops and induce flood risk in some areas. Precipitation directly affects the availability of water for irrigation during the dry season.

Relative humidity: this parameter is only interesting during the vegetation period in spring. It is used to forecast the spread of fungi and bacterial diseases. Higher relative humidity (>75%) is favorable for such diseases. Lower relative humidity during the summer period would increase the water needs of plants. Relative humidity is only accounted for in coastal agricultural areas.

Evapotranspiration (ETP): Studying ETP is essential to estimate eventual changes in water needs of plants, and whether these needs are ensured by rainfall or not. This parameter can be integrated into models to calculate the water needs of plants and to undertake irrigation accordingly. Since changes in evapotranspiration could not be modeled accurately by PRECIS – mostly due to the lack of historical data – this parameter was not used in the assessment, and was replaced by crop water requirements together with projected rainfall.

2.1.2.3. Methods of assessment

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 availability of water and land was assessed taking into consideration the projected growth in population, urbanization, income etc., as outlined in the socio-economic scenarios.

2.1.2.4. Data sources and gaps

The main sources of data for the assessment in the Agriculture sector included:

- MoE's State of the Environment Report
- MoA's Agricultural Census for the year 2005;
- FAO's FAOSTAT and AQUASTAT online databases;
- The World Bank's Lebanon Country Profile; and
- CDR's National Physical Master Plan for the Lebanese Territories (NPMPLT).

Studies relating climatic factors to agricultural production and quality are missing in Lebanon, thus making any quantitative assessment difficult. In addition, the lack of an agricultural policy, leaving the choice of crops to farmers, makes the projection of changes in surface area of specific crops difficult to estimate.

2.1.2.5. Assumptions and limitations

The analysis heavily relied on assumptions given the paucity of empirical studies and data in Lebanon. Among these, it was assumed that farmers tend to adapt spontaneously to some of the features of climate change through, for example, adjusting their pest control techniques, planting dates and choice of crops. Since the direct impact of climate change on yields and crop product quality is not taken into consideration in the agriculture census, and in research topics in Lebanon, we assumed that these parameters vary in the same way as mentioned in the literature. Assumptions in climatic variation with altitude are requisite since the PRECIS accuracy does not take into consideration the different agro-climatic zones of Lebanon.

Finally, the assessment could have better invested into GIS techniques in order to strengthen the results and minimize assumptions. However, the limited availability of data and maps, in addition to time constraints hampered the use of such tools.

2.1.3. Scenarios

2.1.3.1. Socio-economic scenarios

The National Physical Master Plan for the Lebanese Territory (NPMPLT) set out principles of land use in the main agricultural areas (CDR, 2005). The Master Plan provides a strategic vision for land development, and future agricultural land use and management is expected to follow the principles that the NPMPLT has set out.

- Rural regions have delineated the main agricultural areas of national interest. The majority of large agricultural entities has high flood risk and must be considered as unsuitable for construction.
- Projects aiming at quality and output improvements such as irrigation projects, agricultural land consolidation, access to the lands should be part of the national strategy for agricultural development by modernizing the processes and means of production.

- Major agricultural lands of the country could receive buildings and infrastructure for farming or agro-industry, or for individual dwelling of the owner or farmer.
- Restrict the commercial real estate operations and allow the agricultural land consolidation for agricultural lands of national interest.
- Avoid opening new agricultural roads or asphalting existing ones before the classification of agricultural lands that must precede any opening or restoration of roads.
- Waste treatment facilities and proposed landfill sites or other facilities that cannot be located near villages could be located on agricultural lands with the least agricultural value.
- Definition of a policy for the urban development of new villages and cities that have been developed in the center of major agricultural areas.

The CDR defined, in the NPMPLT (2005), different challenges that Lebanon faces today and ones that it might face in the future. According to those challenges and the principles for agricultural land use and development, two possible scenarios were proposed for the development of the agricultural sector by the year 2030. These two scenarios are detailed below.

Scenario A	
▪ Growing integration of international trade, Lebanese production of exchangeable products would not be significantly developed ▪ Less balanced economic development ▪ GDP grows at an annual average rate of 4.2%[1] ▪ Low population growth: Population will grow, however at a decreasing rate – average of 0.35%[2] between 2010 and 2030 ▪ Total urbanized area will slightly increase ▪ The migration balance[3], between 2001 and 2030 will be around (- 27,000) persons yearly ▪ Same standard of living	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.
Scenario B	
▪ Growing integration of international trade, local production could better resist the competition induced by imported products ▪ Balanced economic development ▪ Considerable GDP growth - GDP is assumed to grow at an annual average rate of 8.6% between 2010 and 2030[4] ▪ High population growth - Population will grow at a modest increasing rate with an average of 0.96%[5] between 2010 and 2030 ▪ Total urbanized area will increase with population, growth of 284 km^2 in urbanized	Under this scenario, 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

1 This is an average of the actual GDP growth rate, at constant 1990 prices, between 2000 and 2004 (IMF, 2009).

2 This an average of the population growth rate in a **low-fertility scenario** as projected in the World Population Prospects: The 2008 Revision (UN, 2009).

3 The migration balance is the difference between the number of persons having entered the territory and the number of persons having left the territory in the course of the year. This concept is independent of nationality (Insee, 2010).

4 An assumption, whereby the annual average GDP growth rate would grow by double the IMF-projected average annual growth rate of 4.3%, for the period between 2010 and 2014 (IMF, 2009).

5 This an average of the population growth rate in a **high-fertility scenario** as projected in the World Population Prospects: The 2008 Revision (UN, 2009).

areas ▪ The migration balance, between 2001 and 2030, will be around (-6,000) persons per year. ▪ Better standards of living ~ 2.4 times higher	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.

2.1.3.2. *Climatic scenarios*

The following table summarizes the projections of the climatic factors of relevance to Agriculture for the Mediterranean region and for Lebanon as they figure in the IPCC Fourth Assessment Report and the EEWRC Climate simulations respectively (1).

Table 2-3 Projected change in climatic factors of significance to the agriculture sector

CLIMATE FACTOR	PROJECTIONS FOR THE MEDITERRANEAN REGION[1]	PROJECTIONS FOR LEBANON[2]
Temperature	The annual mean warming from the period 1980-1999 to 2080 -2099 varies from 2.2°C to 5.1°C. The warming in the Mediterranean area is likely to be largest in summer.	Increases in Tmax are projected to be between 1°C on the coast of Lebanon and 2°C inland by 2040, and between 3°C on the coast and 5°C inland by 2090.
Precipitation	The annual area-mean change from the period 1980 -1999 to 2080- 2099 varies from –4% to –27% in the Mediterranean region.	Rainfall reduction is projected to be between -10 and -20% by 2040, and between -25% and -50% by 2090.
Relative humidity		Annual average relative humidity changes will be very small by 2040, but reductions up to -10% in the eastern part are projected for the 2080s.

Sources:

1 Christensen, J.H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R.K. Kolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr and P. Whetton, 2007.

2 Please refer to Section 1

2.1.3.3. *Vulnerability Assessment*

The vulnerability assessment addressed the agricultural sub-sectors that were judged by expert opinion to be most vulnerable to changes in climatic factors and that are important in the Lebanese economy (Table 2-1). The overall vulnerability of crops and sub-sectors was evaluated according to 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.

Sensitivity and adaptive capacity were examined, and an analysis of the vulnerability is presented for each of the crops and agricultural sub-sectors in the sections below with map illustrations showing the worst-case scenario for overall vulnerability. A summary of the overall vulnerability assessment results appears in Table 2-4. The assessment of vulnerability is based on expert judgment and a thorough analysis of the implications of projected changes in climatic factors on crops, supported by a review of the scientific literature. The narrative analysis in this section, map illustrations and summary table are the tools and methods were used to illustrate the expert's judgment and review.

Wheat

Wheat is cultivated in central and west Bekaa, Marjayoun and Akkar plains, as well as in several areas in south Lebanon. In most cases, wheat is rainfed, however, some exploitations benefit from supplementary irrigation in April-May that boost yield if rainfall is not sufficient (MoA, 2007).

Wheat has historically been cultivated in the Mediterranean region. The temperature range in Lebanon is suitable for wheat production. Mild humid winters are favorable for wheat. The limit of wheat production in Lebanon is in areas where annual rainfall is above 400 mm. However, yields are often lower than in other climatic regions due to the lack of rainfall in spring. Hence, wheat yield is mostly correlated to rainfall amount, especially in April, within the Mediterranean region. Tmax in

November and Tmin in March also affect growth and yield (Ventrella, 2006). Higher autumn temperatures will reduce frost risk, while reduced irrigation in spring will affect yields. The most vulnerable areas 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 800mm/year are still considered with moderate risk. As a matter of fact, the carbon fertilization will be barely able to offset yield losses due to climate change. Figure 2-30 illustrates the cultivation patterns and vulnerability of cereals in general, including wheat - the most widely grown cereal crop, with a ranking of the vulnerability by area. The overall vulnerability of wheat and cereals in general to projected changes in relevant climatic factors is considered moderate (Table 2-4).

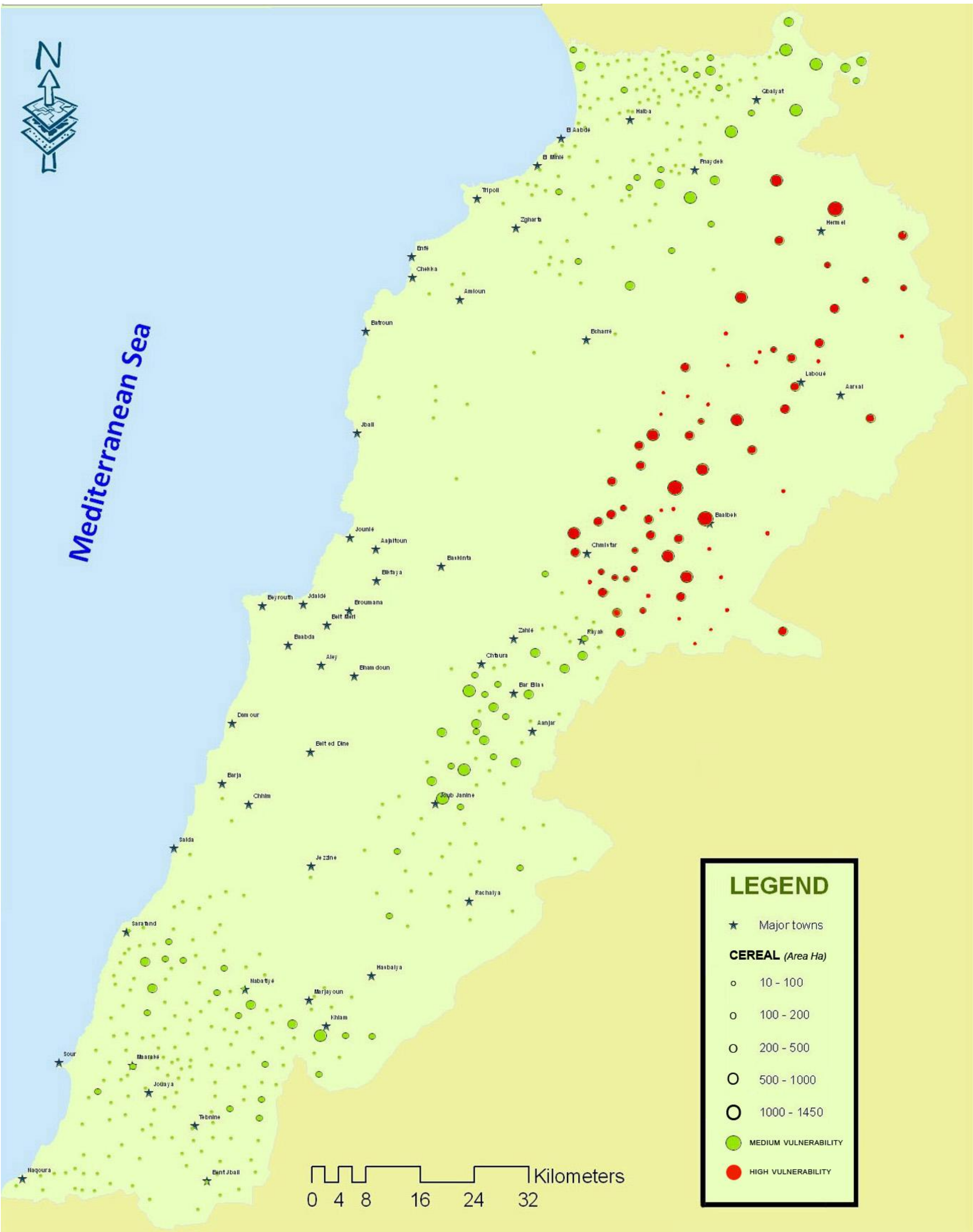

Figure 2-30 Cereals cultivation areas and crop vulnerability

Potato

Potato is the third most consumed crop after wheat and rice in Lebanon. While tender wheat and rice for national consumption are imported, potato is locally cultivated. Thus, potato production is an essential indicator of national food security. Production reached 511,400 tonnes in 2005, over an area of 19,671 ha (Figure 2-5). Potato occupies a major position (among the top four crops) in agriculture exports as well. Two-thirds of the production comes from the Bekaa plain and one-third from the Akkar plain (MoA, 2007).

In the Bekaa plain, potato is cultivated in different periods between February and May, according to altitude. In all cases, potatoes are considered a spring/summer crop. A second potato crop may be planted in summer, and then harvested in autumn. In the Akkar plain, potatoes are planted as a winter crop. Thus, Lebanon has potato production scheduled almost all year round with seven months of harvesting. From January to March, Lebanon relies on imports of potatoes to meet its local consumption needs (MoA & LARI, 2008).

Being a tuber, potato is highly efficient in its use of water. Potato is 100% irrigated in the Bekaa. In, Akkar, irrigation is complementary to rainfall when potatoes are planted as a winter crop (MoA & LARI, 2008). Besides water, tuber formation and starch accumulation require mean day temperatures below 20˚C, and mean night temperatures below 15˚C (Stäubli, B. et al., 2008). Production is affected when temperature is outside the range of 10-30˚C. Hence, winter cropping of potato in Akkar will be 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 2-31 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 (Table 2-4).

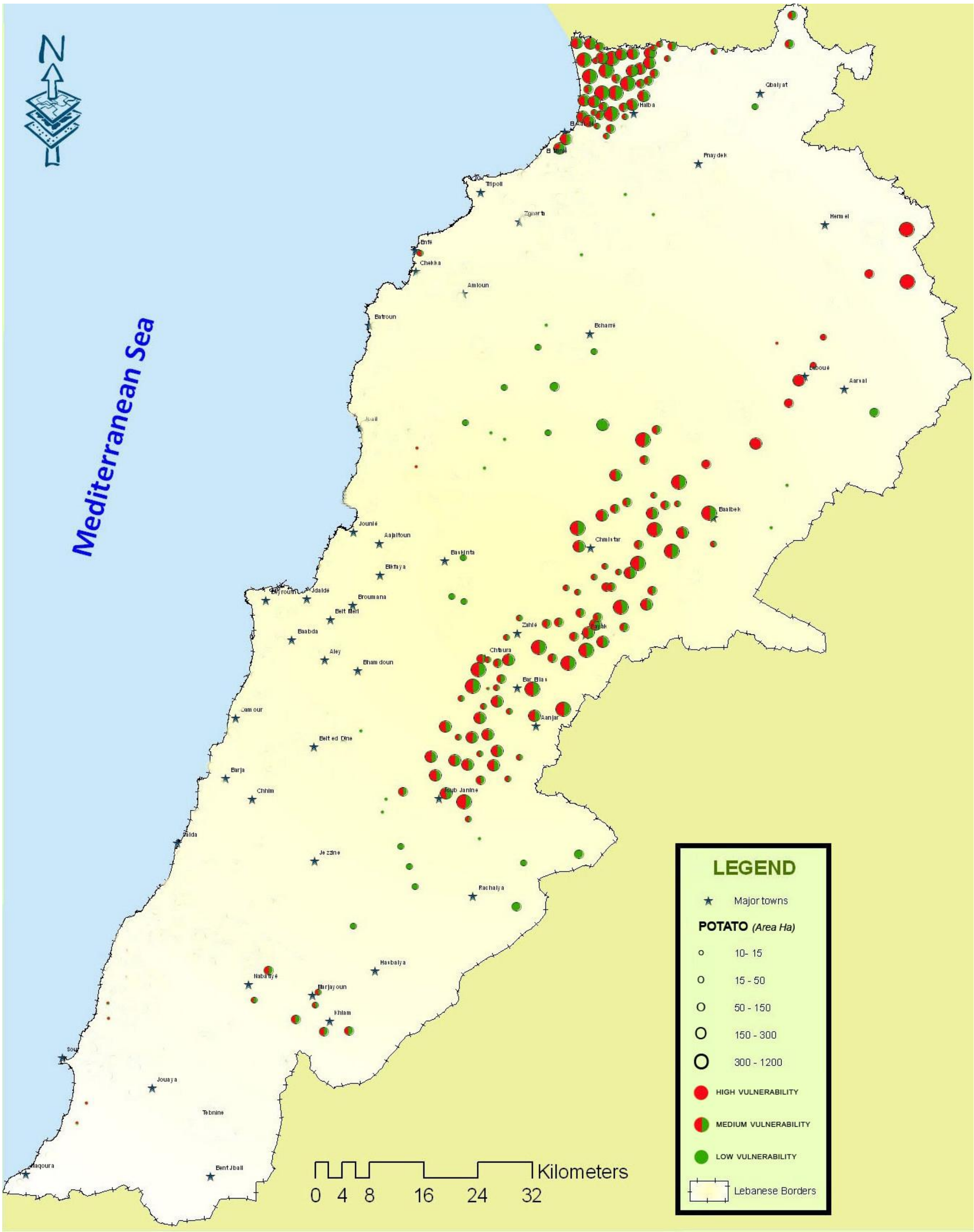

Figure 2-31 Potato cultivation areas and crop vulnerability

Tomato

Tomato is the major fruit vegetable that is cultivated in Lebanon. The area of production was 3,696 ha in 2005 (Figure 2-7). Production reached 277,000 tonnes during the same year. Tomato is cultivated as an annual crop all over the country, and thus tomato growers include a large number of farmers. The biggest areas of production remain the Bekaa valley, Akkar plain, Zahrani plain, as well as coastal areas and mountain villages of Mount Lebanon and North Lebanon. Tomato is grown either in greenhouses or in fields, mostly as an irrigated crop. Due to the diversity of the areas of production, and the possibility of growing tomato as a winter crop (in greenhouses), the locally-grown varieties of tomatoes are found on the market all year round (MoA, 2007).

Tomato is a warm season crop; it requires a warm and cool climate. The tomato plant cannot withstand frost and high humidity. Temperatures below 10˚C and above 38˚C adversely affect the plant's tissues. It thrives well in potato growing areas, when temperatures are between 10˚C and 30˚C with an optimum range between 21˚C and 24˚C. Although the tomato plant is not very water demanding, water stress and long dry periods cause the fruits to crack and reduce the plant productivity (Pervez et al., 2009). For this reason, tomato is grown in greenhouses for at least two rounds per year: a first season between July/August and October/November, and the second between November and February. A third round is possible between February and May. In the Bekaa valley and on medium altitudes (500-1,200 m), one season only is grown between April/May and July/August. On higher altitudes (1,200-2,000 m), the growing season starts in May/June and ends with the first frost in autumn. Tomato seedlings are sometimes grafted for better performance and to avoid soil-borne pathogens (MoA & LARI, 2008).

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 an expansion of the growing season due to delayed autumn frost. 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. Water demand of plants would increase for both greenhouse and field tomato production, regardless of the eventual anticipation of plantation dates for field cropping (Ventrella, 2006).

Hence, the vulnerable areas of production are in medium altitudes including Bekaa and Marjayoun plains. If early planting could save losses from temperature extremes, water demand cannot be ensured as water availability for irrigation is likely to decrease. A more dramatic situation would be observed in greenhouses and coastal areas, as water would be less available. In addition, increasing demographic pressure would induce an increase in water salinity due to excessive pumping and saline intrusion and would lead to an increase in land prices due to urban expansion. Tomato production in these areas could be relocated.

The less vulnerable areas of production would be the higher altitudes where negative effects of rising temperatures and reduction in water availability are less foreseen. Figure 2-32 illustrates the cultivation areas and vulnerability of the tomato crops to the projected changes in climatic factors with a ranking of vulnerability by area. The overall vulnerability of the tomato crop is considered moderate (Table 2-4).

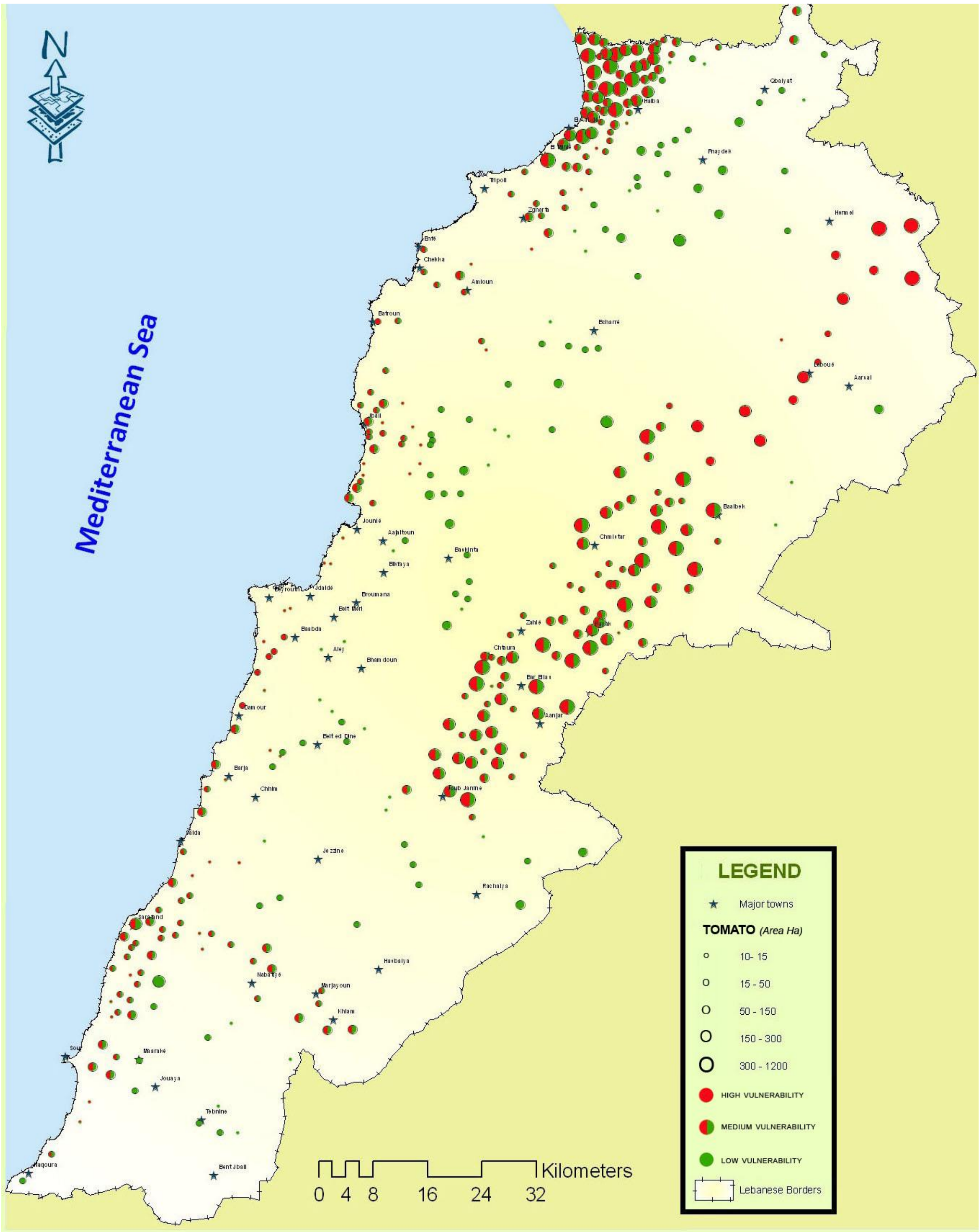

Figure 2-32 Tomato cultivation areas and crop vulnerability

Cherries

Cherries are grown in Lebanon in temperate regions, on altitudes varying between 900 m and 2,000 m. Sweet cherry orchards cover more than 7,700 ha (Figure 2-11), mostly located in Mount Lebanon and Bekaa. Production was estimated at 29,600 tonnes in 2005 (MoA, 2007). Orchards are mostly irrigated; however, at higher altitudes in the plateau of Aarsal, most orchards are rainfed. The rootstock used, *Prunus mahaleb*, is drought-tolerant, and has replaced the old rootstock, *Prunus avium*.

Cherry blossoming occurs in April, and harvesting is carried out between mid-May and late July, according to the cultivar and to altitude (MoA & LARI, 2008).

Cherry blossom is sufficiently robust against short spring frost, but it is likely to be more sensitive to high temperatures (over 21˚C). Hail and rain occurring late in May or June may affect the quality of fruits to a certain extent (Lichou et al., 1990) Chilling requirements are relatively high for cherry, as most of the local cultivars would need more than 700 hours of chilling which is equivalent to 70 days with 0˚C <Tmin <7.2˚C. If chilling hours are not ensured, the production potential is reduced. Higher temperatures with limited frost days in winter would also increase the multiplication of wood insects.

Cherry production covers large areas at lower altitudes, of 900-1,000m. However, these orchards gave lower yields during the last decade due to several problems such as rootstock die back, wood insect outbreaks, spring frost, and deficient chilling requirements. The ongoing sanitation *of Prunus mahaleb* will enable the production of rain fed, or complementary irrigated, cherries in the entire production zone, bypassing water shortage for irrigation. Vulnerability will be thus only due to temperature increase in winter and during blossom. The Central Bekaa will remain highly vulnerable; altitudes between 1,200 and 1,400m are moderately vulnerable. Figure 2-33 illustrates the cultivation patterns and vulnerability of cherry with a ranking of vulnerability by area. The overall vulnerability of the crop is considered moderate (Table 2-4).

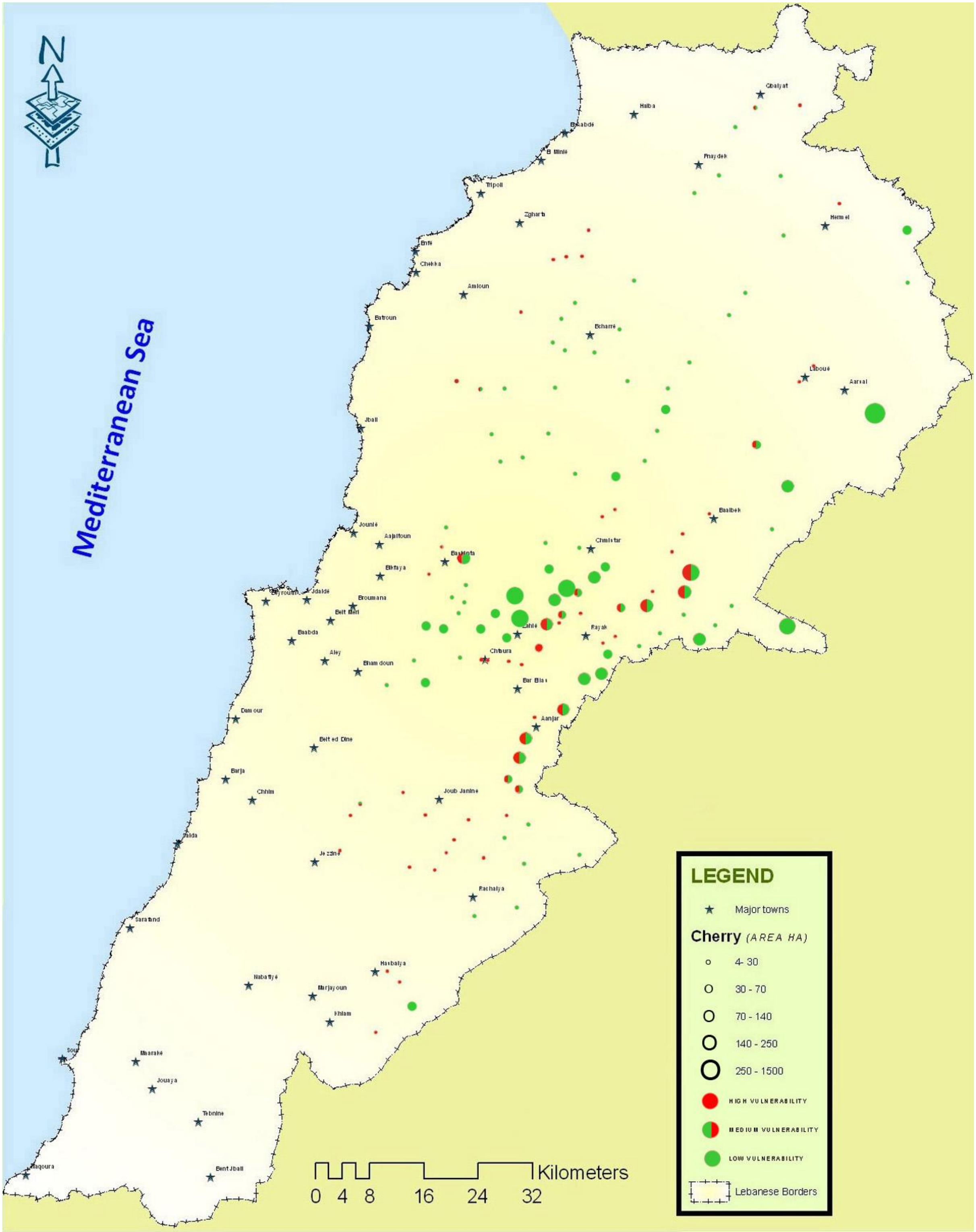

Figure 2-33 Cherry cultivation areas and crop vulnerability

Apples

Apples are one of the most important crops grown in Lebanon, with 114,800 tonnes produced in 2005 (MoA, 2007). The area of plantation is around 9,400 ha (in 2005 (Figure 2-13), located mainly between 900 m and 1,900 m of altitude. Most of the production areas are located in North Lebanon, Mount Lebanon and the Bekaa. Almost all of the orchards are irrigated. Apple is the most cultivated fruit species by area, and is the second highest agricultural product marked for export (MoA, 2007).

Apple blossoming occurs in April. Harvesting dates vary according to the cultivar, but usually extend between late June and late October. However, most of the crop is harvested during September and October (MoA & LARI, 2008).

Apple blossom is sensitive to spring frost and hot and dry winds. Hail and rain late in May or June or later in October may affect the quality of fruits. High temperatures (>40˚C) accompanied with drought conditions and less cloud cover increase the risk of sunburn to fruits (Trillot et al., 2002). Chilling requirements vary according to the cultivar, from less than 400 hours (low chilling requirement cultivars), to more than 900 hours (Steffens and Stutte, 1989). If chilling hours are not ensured, the production potential is reduced (Austin and Hall, 2001). In general early cultivars with lower chilling requirements are planted at lower altitudes in the Bekaa valley. Standard varieties are mostly planted above 1,200 m in most regions. However, vulnerability from temperature increase is not the only factor to be accounted for. Demographic pressure in Akkar, the Bekaa and some other areas combined with water scarcity for irrigation will intensely affect the production. Thus, large areas of production will suffer from the lack of water for irrigation, and other areas in lower altitudes will have a diminishing yield due to the decrease in chilling hours. Figure 2-34 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 to changes in climatic factors is considered high (Table 2-4).

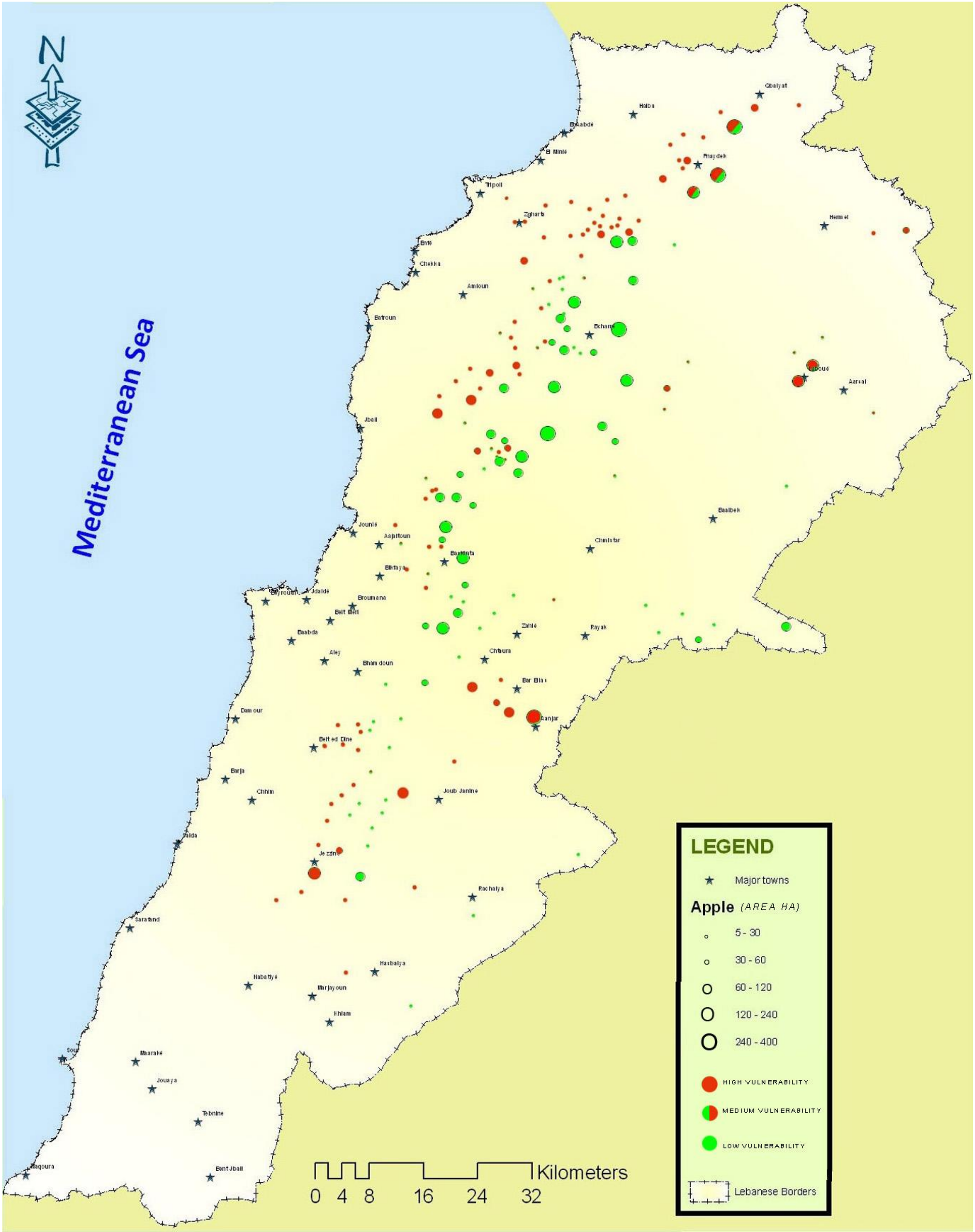

Figure 2-34 Apple cultivation area and crop vulnerability

Grapevine

Grapevine is cultivated in Lebanon for both table grapes and industrial processing (arak, wine, molasses…). Cultivation for table grapes covered 9,915 ha while cultivation for agro-food processing occupied 2,880 ha in 2005 (Figure 2-12). Production reached 99,100 tonnes and 11,500 tonnes for table and industrial grapes, respectively, in 2005 (MoA, 2007).

Most of the area of production is located in the Bekaa valley and Akkar, with few vineyards in Mount Lebanon and the South. A part of the production is exported (Figure 2-17); 40% of the eight million wine bottles produced were exported in 2005 (MoA, 2007) (Figure 2-18).

Vineyards for table grape production in the Bekaa and Akkar are irrigated in general, while industrial production is rainfed. The natural limit for vines is around the isohyets of 300 mm annual rainfall in northern Bekaa, and from sea level up to 1,650m in altitude (MoA & 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. Both table and industrial grapes require infrastructure for training the vines and supporting them. In most cases, vines are trained on a pergola for table grapes, and on hedges for the wine industry. The selected rootstocks are more or less tolerant to drought, calcareous soils and phylloxera. The most commonly used rootstock is 41B (MoA & LARI, 2008).

Grapevine is a Mediterranean species that requires a long warm summer and a mild winter. It tolerates drought and can survive rainfall of no more than 300 mm a year. On the contrary, humid spring and summer seasons would negatively affect yields and the quality of the crop. Table grapes tolerate high Tmax over 40˚C, yet heat waves should not last days as fruit quality will be altered when Tmax 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). Figure 2-35 illustrates the cultivation areas and vulnerability of grapevine to projected changes in climatic factors with a ranking of vulnerability by area. The overall vulnerability of the grapevines crop is considered moderate (Table 2-4).

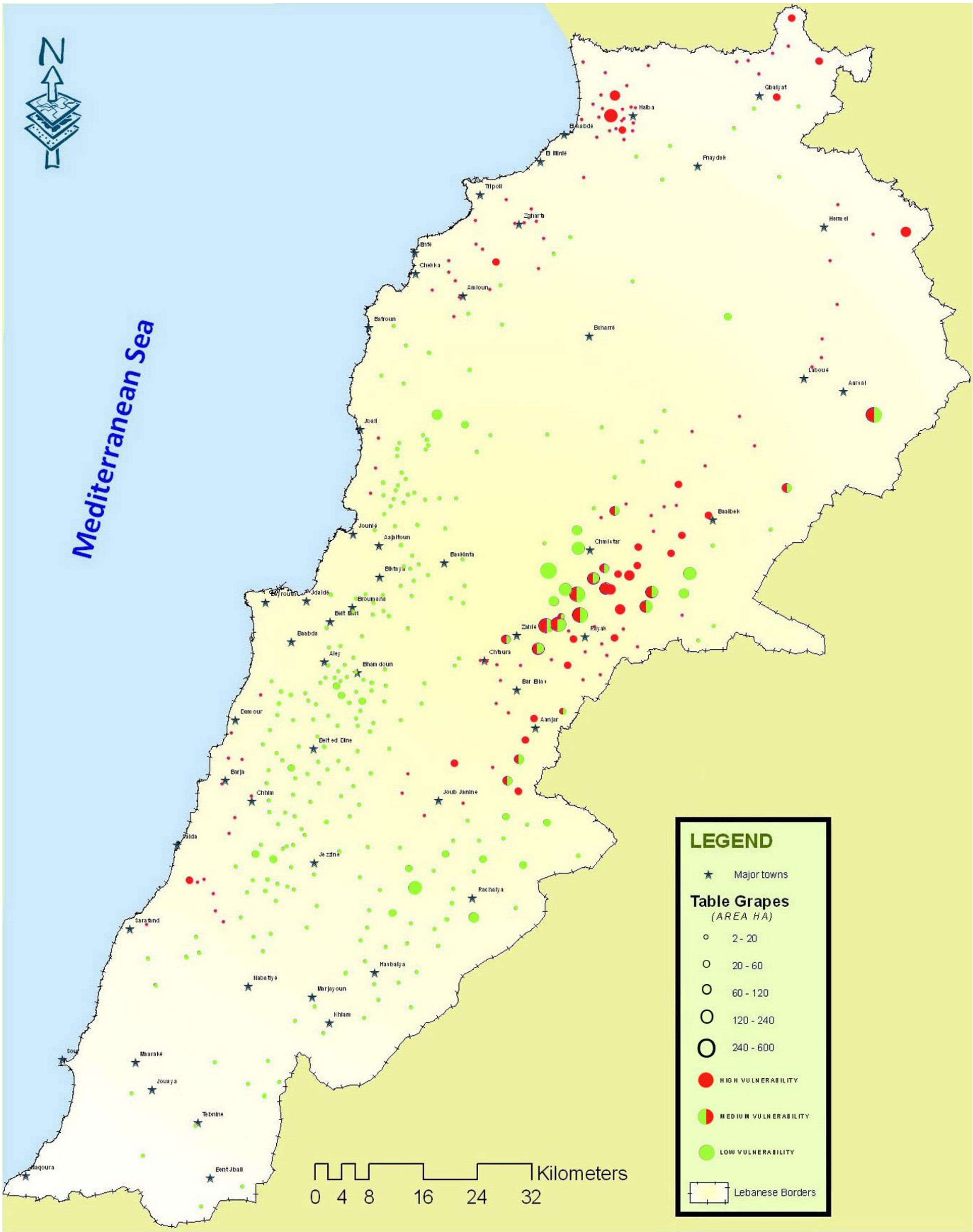

Figure 2-35 Grapevine cultivation areas and crop vulnerability

Banana

Banana is one of the most important fruits worldwide. In Lebanon, it figures among the major cultivated crops, especially on the coast where it is gradually replacing citrus orchards. In 2005, banana crops covered 2,800 ha (Figure 2-12) producing more than 81,200 tonnes. Production is concentrated in South Lebanon and Mount Lebanon; however, production in Mount Lebanon is lower. Local production covers the national consumption demand, and the surplus is exported to Syria (MoA, 2007).

Banana has been historically planted on the coastal area between Byblos and the southern border, with an altitude rarely exceeding 150 m in south Lebanon, mostly due to the lack of water availability at higher altitudes. Recently, banana plantations in greenhouses have been introduced.

Banana is a tropical fruit that requires heat and humidity, and cannot withstand frost. Hence, banana requires large amounts of irrigation water to ensure its needs during the arid season. Banana is usually planted for a two-year growth period. Land and water availability will be reduced due to demographic pressure (mainly in Mount Lebanon, and around Saida and Tyre). The reduction of water availability combined with higher demographic pressure and demand for built areas will reduce irrigated areas. More frequent sea intrusion into the water table, and higher water salinity will also hinder banana growing in many southern coastal areas. 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. Figure 2-36 illustrates the cultivation areas and vulnerability of the banana crops to projected changes in climatic factors with a ranking of vulnerability by area. The overall vulnerability of the crop is considered low (Table 2-4).

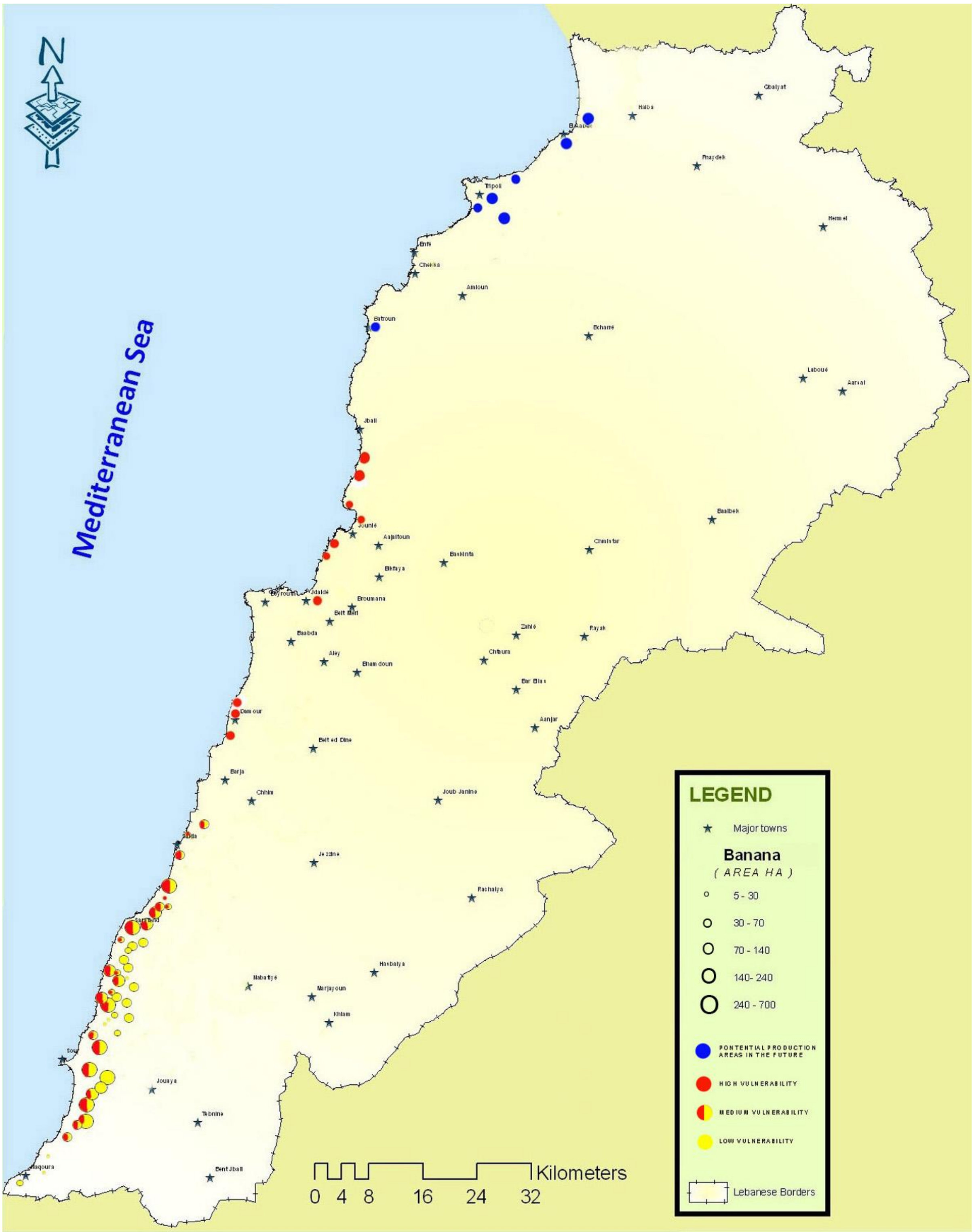

Figure 2-36. Banana cultivation areas and crop vulnerability

Olive

Olive tree orchards are mostly non-irrigated. Olive groves in areas that receive less than 300mm of annual rainfall, e.g. Hermel, rely on irrigation to ensure a profitable yield. Most of the yield is designated for olive oil production. For this purpose, local cultivars are the most widely planted. European varieties are only grown for olive fruit consumption, and whenever irrigation is ensured (MoA & LARI, 2008).

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 is a typical Mediterranean species that can withstand long drought periods and high temperatures (above 40˚C). It can be grown in areas with annual rainfall below 300 mm. The olive tree needs water for enabling blossom and fruit formation. Due to the size of the fruit, 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 and freezing winter temperatures as Tmin falls below -5˚C. Spring frost and hot dry winds would jeopardize production (MOA & LARI, 2008, Loussert & Brousse, 1978). Nevertheless, an olive tree's chilling requirement is estimated at 200 to 300 hours. Hence, olive tree groves are found on the western slopes of Mount Lebanon and Mount Hermon below 1,000 m in general, and rarely in the Bekaa valley.

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 500m, 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 1,300m as warmer temperatures set in. The moderate vulnerability in some coastal zones is due to the persisting humidity, decrease in chilling hours as well as the demographic pressure over the land. The olive groves of northern Bekaa which are totally irrigated are highly vulnerable in case of water scarcity and extreme climatic conditions. Figure 2-37 illustrates the cultivation areas and vulnerability of olive trees to projected changes in climatic factors with a ranking of vulnerability by area. The overall vulnerability of the olive crop is considered low (Table 2-4).

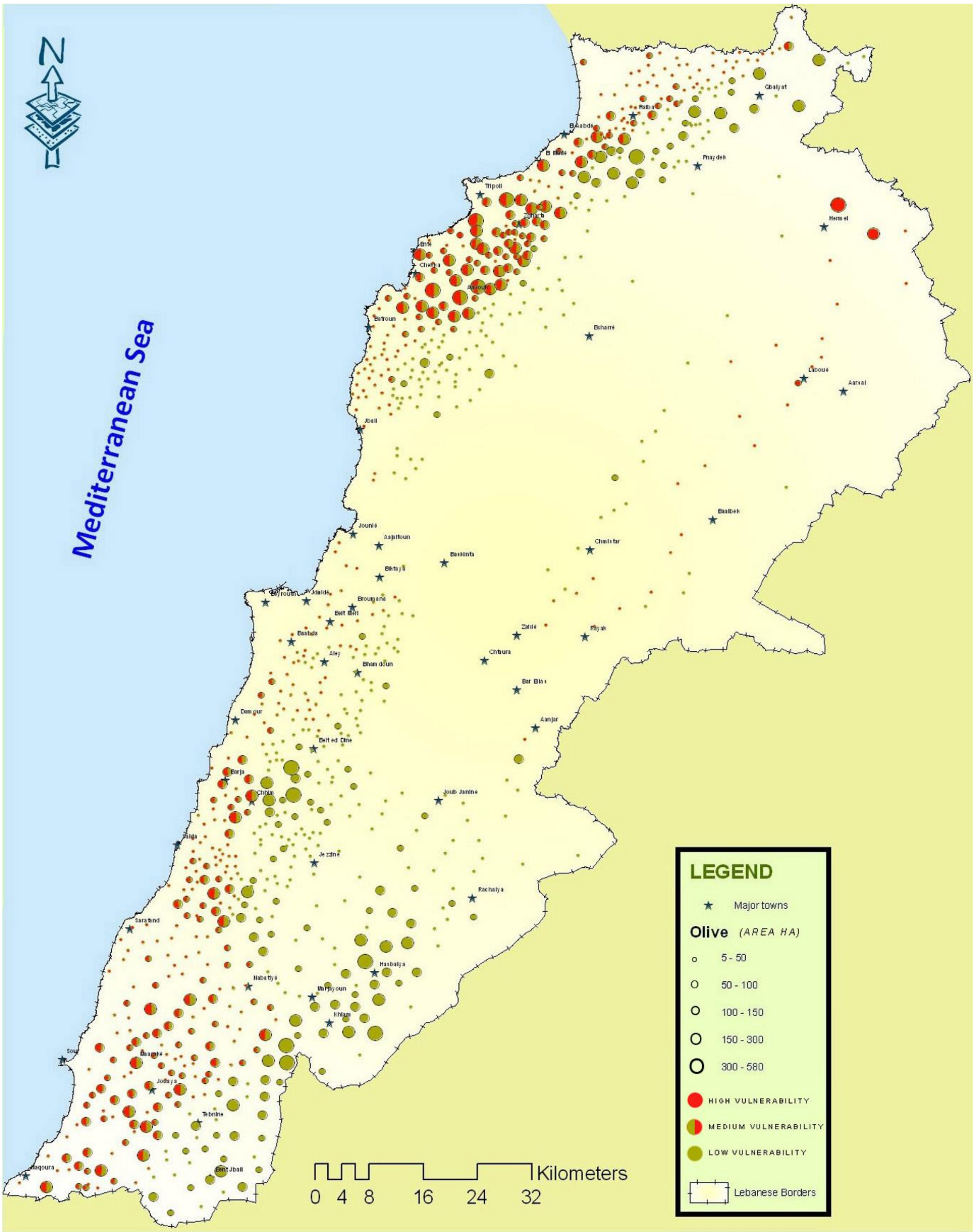

Figure 2-37 Olive cultivation area and crop vulnerability

Small ruminants

Rangelands provide the bulk of livestock food needs. The area of these rangelands is difficult to assess and all figures are around half of the country's area. In Mediterranean areas, natural permanent pastures are almost absent. Seasonal pastures are located mainly on mountain tops, in the Bekaa northern steppes, as well as in few other areas (Gintzburger et al., 2006). This has induced the shepherds to invest in other land uses such as forests, other wooded lands and in agriculture areas, specifically post-harvest fields and fallows. When grasslands are scarce, shepherds tend to complete nutrient ratios by imported fodder, concentrates and local agricultural residues. In all cases, the increasing reliance on feed blocks and feed supplements for ruminants could lead to a decreased vulnerability of animal production to climate change, since the feed is provided regardless of the availability of grazing (Enne et al., 2002).

The length of the grazing period and the quality of pastures are highly affected by the amount and distribution of precipitation, and by temperature. These factors affect evapotranspiration (ETP) and consequently soil moisture content (Fleischer and Sternberg, 2006). Temperatures between 10˚C and 25˚C are favorable for grass. Lower temperatures will slow down their growth, and stop it when frost occurs. Ice and snow covers will delay grass development, however they would provide a valuable pasture later during the summer dry season. Temperatures above 25˚C will increase ETP, thus reducing soil moisture and the viability of grass, especially if rain is delayed.

Local *Awassi* sheep and *Black goat* are fully adapted to these extreme conditions in terms of temperatures and drought. These races could still produce milk and meat, even with annual precipitations averaging 200 mm or less. Yet, their productivity would decrease (Gintzburger et al., 2006). The overall vulnerability of small ruminants is considered high (Table 2-4).

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 (Reidsma and Ewert, 2008; Oxfam, 2009). Systems featuring small scale farming, diversity of products within a region and at farm level have shown better resilience and adaptation to extreme climatic events than other agriculture production systems.

Lebanese agriculture is depicted by several criteria which illustrate resilience and adaptation to climate change. The 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/FAO, 2005a). 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/AUB, 2009). Strategic crops for food security in Lebanon can be reduced to wheat (although durum wheat is not suitable for bread industry), potato, poultry meat, red meat, milk and olive oil. Beetroot cultivation for sugar production has ceased as it was not sustainable within the Bekaa. 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.

A summary of the vulnerability assessment findings per crop type and agricultural sub-sector is provided in Table 2-4.

Table 2-4 Analysis of overall vulnerability of agricultural crops and sub-sectors

SYSTEM	SENSITIVITY	ADAPTIVE CAPACITY		OVERALL VULNERABILITY
Wheat	Moderate	Scenario A	High	Moderate
		Scenario B	Moderate	
Potato	High	Scenario A	Moderate	High
		Scenario B	Low	
Tomato	Moderate	Scenario A	High	Moderate
		Scenario B	Moderate	
Cherry	Moderate	Scenario A	Moderate	Moderate
		Scenario B	Low	
Apple	Moderate	Scenario A	Moderate	High
		Scenario B	Low	
Grapes	Low	Scenario A	Moderate	Moderate
		Scenario B	Low	
Banana	Moderate	Scenario A	High	Low
		Scenario B	Moderate	
Olive	Low	Scenario A	Moderate	Low
		Scenario B	Moderate	
Small ruminants	High	Scenario A	Moderate	High
		Scenario B	Low	

2.1.4. *Impact Assessment*

2.1.4.1. *Selected impact indicators*

The following indicators (Table 2-5) were selected to assess the impact of climate change on the vulnerable systems identified, under each of the two socio-economic scenarios.

Table 2-5 Indicators for analysis of climate change impacts on vulnerable systems in agriculture

VULNERABLE SYSTEM	INDICATOR	RELEVANCE
Wheat	Productivity	Wheat productivity is closely related to changes in precipitation.
	Cultivated area	Areas below 400 mm isohyets cannot be cultivated with wheat.
Potato	Cost of irrigation ($/ha)	Potatoes rely mostly on groundwater for irrigation. A lower water table induced by a decrease in precipitation coupled with increased demand will increase the cost of pumping.
	Agricultural export volume and value	Changes in the cost of production and harvesting periods will negatively affect the export volume and value.
Tomato	Productivity	Increase in temperature negatively affects tomato productivity and quality.
Cherry	Productivity	Cherry productivity is related to changes in temperature.
	Cultivated area	Orchards below 1,300 m of altitude are highly affected by temperature.
Apple	Agricultural export volume and value	Apple is a major economical crop in mountains, and is affected by changes in temperature and precipitation.
	Percent of orchards under drip irrigation	Orchards that are mostly irrigated by gravity will shift to drip irrigation with increasing water scarcity.
Grapevine	Agricultural export volume and value.	The quality of table grapes and industrial grapes is affected by temperature; and fresh grapes and wine are highly exportable commodities.
Banana	Agricultural export volume and value	Bananas are exclusively exported to Syria in considerable volumes. Climate change might favor banana cultivation in

VULNERABLE SYSTEM	INDICATOR	RELEVANCE
		Syria and other Mediterranean countries, therefore increasing market competition.
	Cultivated area	Urban expansion and soil salinization will negatively affect the cultivated area of bananas.
Olive	Productivity	Olive productivity is indirectly affected by temperature, precipitation and humidity, through increased outbreaks of pests and diseases.
Small ruminants	Number of heads of small ruminants (goats and sheep)	The number of heads of small ruminants reflects the availability of pastures and the cost of production, which are affected by climatic conditions.
	Total production of milk	Milk production indicates the quality of pastures and the length of the grazing period, which are directly affected by climatic conditions.

2.1.4.2. *Impacts due to climatic and non-climatic factors*

Possible impacts from climatic change on irrigation and agricultural crops were investigated in the Nahr Ibrahim basin (Hreiche et al, 2007). The conceptual rainfall-runoff model used in the study area showed that the water shortage period in the basin would be prolonged by 15 days to one month, thus resulting in a shift of the production at the same output rate. While this change is not expected to affect perennial crops, annual crops would have to be sowed earlier. The authors conclude that this impact would not warrant significant adaptation beyond the usual measures that farmers take to account for inter-annual variability of the irrigation water supply (Hreiche et al, 2007).

The impacts of projected changes in climatic conditions and changes in socio-economic conditions are discussed in this section by agricultural crop and sub-sector. The analysis of possible impacts uses the above-listed indicators (Table 2-5), 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 two different socio-economic scenarios, reported accordingly in Table 2-6.

Wheat

The PRECIS model simulation does not show a significant effect of temperature changes on the production of wheat in Lebanon. Precipitation patterns in spring are likely to remain as such until 2098, with no evidence of significant change; soil moisture will be decreasing due to higher spring temperatures and higher evapotranspiration (ETP). Carbon fertilization could offset eventual yield decrease until the 2040s. Yet, the increasing aridity will definitely reduce yields in the second half of the century.

Since the onset of the rainy season defines sowing date, all areas of production will be facing a shorter period of growth. An overall increase in temperature and ETP would decrease soil moisture and consequently yield, if rain or complementing irrigation does not occur in spring. Hence, the limit of wheat production in central Bekaa would shrink within the 400 mm isohyets.

Consequently, all areas of wheat production are subject to yield variation, but yield variation is very controversial and difficult to assess. Productivity and the cultivated area of wheat were used to illustrate the impact of climate change on this crop under two different socio-economic scenarios (Table 2-6). Wheat productivity is expected to increase, and the total wheat cultivated area is projected to remain stable (Scenario A) or slightly decrease (Scenario B).

Potato

During the actual, current scenario, 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. As of the 2030s, Tmax average will be over 30˚C starting the month of June, while the risk of frost will decrease in March (1 day) and February (2 days), with an average Tmin between 4.6˚C and 5.6˚C for the two months respectively. By 2099, the risk of frost will be less than 1 day per month for the three winter months, and average Tmax will be 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 Tmin in summer nights will increase (Tmin 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.

In Akkar, in the near future (2025-2044), the production would be optimal, with monthly Tmax below 20˚C, Tmin above 10˚C for the period from November to March and with more than 560 mm of rainfall. By the 2080s, Tmax will be slightly above 20˚C, Tmin around 15˚C and rainfall roughly 510 mm, and thus production will start declining.

To conclude, potato growers in Akkar will see their profits increase as their yields will be increasing, especially during the 2030s and through to the 2050s. Bekaa growers will see their profits increase from early cropping, but might lose if they plant later in the spring/summer season. However, winter potato growers will be facing more fungi and bacterial diseases, such as late blight, Brown rot and Erwinia due to the combined relative humidity and temperature increase (Haverkort, 2008). Nematodes and Aphids infestation may be amplified, especially in Akkar. By 2080, the harvesting period will shift and the import period is likely to shift to the months between September and November.

The cost of irrigation as well as the agricultural export volume and value for potatoes were used to illustrate the impact of climate change on this crop (Table 2-6). The overall impact in both scenarios is expected to be a high increase in the cost of irrigation and a high decrease in the export volume and value.

Tomato

Tomato production will be slightly affected by temperature rises by the 2030s, but yield decrease could be significant by the end of the century. The growing period will be shorter, with less fruit set in summer due to temperature extremes and water shortage, especially in the Bekaa and medium altitudes. On higher altitudes, the diminishing production in summer could be counterbalanced by an extension of the growing season due to retarded autumn frost. Increasing carbon concentration in the air will offset eventual production losses in greenhouses resulting from higher temperatures and relative humidity levels during the spring and summer/autumn growing seasons. Water demand of plants will increase for both greenhouse and field tomato production, regardless of the eventual anticipation of plantation dates for field cropping.

Hence, the vulnerable areas of production are in medium altitudes including the Bekaa and Marjayoun plains. While planting early could save losses from temperature extremes, water demand cannot be ensured as water availability for irrigation is expected to decrease. A more dramatic situation will be observed in greenhouses and coastal areas, as water will be less available. A tremendous demographic pressure (see Figure 2-28) causing an increase in water salinity due to excessive pumping and saline intrusion added to an increase in land prices due to urban expansion will exacerbate the risks from climatic change. Tomato production in these areas could be relocated.

The less affected areas of production will be the higher altitudes where negative effects from temperature increase and the reduced water availability will be lower in magnitude.

The productivity of tomatoes was used to illustrate the impact of climate change on this crop (Table 2-6). 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.

Cherry

The PRECIS model data allowed the generation of the number of days on which Tmin falls between 0˚C and 7.2˚C at different altitudes. For instance, at 1,000 m, which is the lower altitude for commercial cherry orchards, the data indicate that under the current climatic conditions, the number of days was 113 between November and March. The model shows that for 2024-2044, this period will be reduced to 105 days. There will only be 74 days of an adequate Tmin range requirement by the end of the century. On the basis of 6 hours of Tmin per day, we estimate that chilling needs will barely be met by 2024 (630 hours), and would be below what the cherry crop needs by the end of the century (444 hours). Chilling requirement needs, however, would not be affected above 1,300 m.

Climate simulations showed that the percentage of days with Tmax>25˚C during the month of April at an altitude of 1,000 m on the western slopes of Mount Lebanon, will increase from 16% during the current period to 18% between 2024 and 2044, to reach 27% of the days in April by the end of the century. At a similar altitude in the Bekaa valley, where a continental climate dominates, the percentage of days with Tmax>25˚C during April will rise from 19% to 20% and 43% for the three respective periods. This means that the risk of failure of blossom pollination and fecundation will increase by 30% in Mount Lebanon and up to 50% in the Bekaa valley. In the latter situation, it is more likely to have one year out of two with low production due to high spring temperatures. Moreover, a spring rise in temperature would increase the rate of infestation by the cherry fly. These risks are low at altitudes higher than 1,500 m.

Precipitation amount and number of days with rain in spring do not seem to change significantly (PRECIS shows an increase in rainfall and number of rainy days for the Bekaa), which means that rainfed irrigation of cherry in the Anti-Lebanon chain at altitudes above 1,500 m should not be significantly affected, even if soil moisture will be 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.

All the above-mentioned simulated figures lead to the conclusion that cherry crops grown at altitudes below 1,300 m will be loss productive with time. The most affected crops would be those in central Bekaa where orchards are located at the lowest altitudes (900-1,300 m). Since there is no clear correlation between chilling time accumulation and blossom, and between maximum daily temperatures and yield, it would be difficult to estimate actual losses in yield, in spite of carbon fertilization.

Productivity and the cultivated area of cherry were used to illustrate the impact of climate change on this crop (Table 2-6). Despite the projected negative effect of climatic changes on productivity, it is expected to remain stable under both socio-economic scenarios due to improved agricultural practices. While the slight increase in cultivated areas that is expected to occur under the climate scenario will not be jeopardized by socio-economic condition under Scenario A, it is projected that increased urbanization under Scenario B would result in a constant cherry cultivation area.

Apple

Climatic data generated by the PRECIS model is used to calculate if the chilling requirements of apple cultivars are met at different altitudes. The current 678 hours at 1,000 m which are sufficient even for high demanding chilling requirement cultivars such as Golden Delicious, will decrease to 444 hours by the end of the century. This means that high and moderate demanding cultivars, over 600 hours of chilling requirement, will bear less fruit. At 1,500 m, chilling requirements will be ensured.

Since apple orchards are irrigated in general, precipitation patterns do not directly affect the production. If a shortage in irrigation water occurs, production will be affected. Water demand will rise with increasing ETP. 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.

Agricultural export volume and value, as well as the percent of apple orchards under drip irrigation were used to illustrate the impact of climate change on this crop (Table 2-6).

Grapevine

The current climatic conditions characterized by the lack of rain during the vegetation period, high day temperatures and cool night temperatures are optimal for both table grapes and wine production in the Bekaa valley and other areas of Lebanon.

Climatic projections show that Tmax will be the major limiting factor for table grapes in both the Bekaa and Akkar, followed by the availability of water for irrigation. Higher temperatures leading to an early bud burst would increase the vulnerability of the crop in an eventual risk of spring frost (Quirk, 2007) in the Bekaa. Véraison stage would be earlier, which means that fruits will be exposed to sunburn, in the case of sensitive cultivars, and fruit ripening will be earlier. Water demand will rise due to excessive ETP. For rainfed table grapes and industrial grapevines, Tmax and precipitation amount will both affect production and quality of grapes, leading to an eventual decrease in yields and a change in wine quality. Low altitude areas which receive low amounts of precipitation would be most affected.

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.

To conclude, 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.

The agricultural export volume and value of grapevine was used to illustrate the impact of climate change on this crop (Table 2-6).

Banana

The climate conditions predicted by PRECIS for the near (2025-2044) and far (2080-2098) 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. Moreover, banana plantations could be expanded to higher altitudes (by 150 m at least) and further north in latitude to the Syrian coastal plain. However, the frequency of nematodes, viruses and fungal diseases is expected to concurrently increase. Moreover, water demand would be higher due to the decrease in soil moisture during most of the year.

The limiting factors for banana growers will be indirectly related to climate change.

The cost of irrigation and the cultivated area of bananas were used to illustrate the impact of climate change on this crop (Table 2-6).

Olive

On the coastal area below 500 m of altitude, olive groves are mostly located in areas having annual rainfall between 600 mm and 1,000 mm. A slight yield reduction could be observed by the end of the century in areas with minimal precipitation rates, due to a decrease in rainfall and a decrease in the chilling period (from 37 days to 4 days) which will however be partially offset by carbon fertilization (California Energy Commission, 2009).

In all areas, an increase in temperature would lead to an increase in the proliferation of the olive fly (California Energy Commission, 2009). An increase in humidity on coastal areas would also amplify the infestation of the olive moth.

In conclusion, 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 500m, specifically Akkar, Zgharta, Koura, Batroun, Saida, Tyre and Nabatiyeh, will face reductions in yields.

The productivity of olives was used to illustrate the impact of climate change on this crop (Table 2-6).

Small ruminants

Small ruminants include sheep and goats in Lebanon. They are characterized by their high dependency on natural rangeland in Mediterranean and semi arid areas. Livestock rearing is concentrated in the Bekaa valley, and seasonally migrates between the valley and the surrounding mountain chains, especially during the summer.

The major issue is the assessment of the nutrient value of the pasture through the study of the carrying capacity and the calculation of the Animal Unit Month (AUM)[6] for a defined pasture area. The degradation of vegetation cover in many rangelands in Lebanon is 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.

The climatic simulations show an increase in temperature and a slight decrease in rainfall by the 2030s. Lower altitudes will have an increase in their herbaceous biomass during winter due to optimal temperature and humidity conditions, coupled with carbon fertilization. Yet, by the end of the century, the pasture season will be shorter; the decreasing soil moisture starting April will shorten grass life. In such a situation, the grazing season could be extended in medium altitudes (1,000 m-2,000 m), while the potential lack of snow during winter will enable grazing for a few additional months. On higher altitudes (> 2,000 m), snow cover might have reduced thickness and a lower residence time as a result of higher temperatures and decreased precipitation, leading to an earlier pasture season. Higher temperatures and the low soil moisture will degrade these grasslands given the decrease in biomass

6One AUM is equivalent to the quantity of fodder consumed by one cow in a period of one month.

and the shorter pasture period. The ecosystem would eventually change as the tree line will go higher in altitude. By the 2080s, in the Bekaa valley, areas having an annual precipitation below 400 mm will be facing additional reduction in rainfall (up to 35%), which would hamper the development of agriculture. Grasslands would move southward in the northern Bekaa plain to invade abandoned agriculture areas. The grazing period will be shorter, as higher spring temperatures will reduce the growth period of grass. 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 consequently 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 is that it is likely to adversely affect soil stability and increase erosion.

In conclusion, all rangeland areas are vulnerable. Mountain tops above 2,000m are the most vulnerable. Northern Bekaa grasslands are likely to be degraded and deserted, however they might expand southward at the expense of agricultural land. The shorter pasture season on the lower altitudes (below 1,000 m) would be partially compensated by an increase in herbaceous biomass. On medium altitudes (1,000 - 2,000m), herders would benefit from a longer pasture season, but with a decreasing herbaceous biomass. The nutritive quality of all rangeland would be negatively affected. Livestock is likely to become more dependent on forage imports to complete their ratios.

The number of heads of small ruminants and the total production of milk were used to illustrate the impact of climate change on this crop (Table 2-6).

2.1.4.3. Summary of impact assessment results

Table 2-6 illustrates the impacts of climate change on the vulnerable systems identified, using the selected indicators.

To conclude, it is shown that climate change and future development trends which disfavor agriculture will negatively affect the sector on the overall. Irrigated crops will face water shortages and an increase in the cost of production (e.g. cost of water pumping). The value of exported crops will decrease (e.g. apple, table grapes, potato and banana). Rainfed crops will show either no change or a decrease in their surface area or productivity (e.g. olive, wheat and cherry). Small ruminants will be highly affected which induces a decrease in livestock number and to a lesser extent in milk production. Hence, the most systems subject to high impact from climate change will be potato, small ruminants and apple. Tomato and banana will be the less affected.

Table 2-6. Impacts of climate change on specific indicators

VULNERABLE HOTSPOTS	INDICATORS	CHANGE IN INDICATORS UNDER NON-CLIMATIC (BUSINESS-AS-USUAL) SCENARIOS		CHANGE IN CLIMATIC FACTORS	CHANGE IN INDICATORS UNDER THE CLIMATE CHANGE SCENARIO	OVERALL CHANGE IN INDICATORS	
Wheat	Productivity Cultivated area	Scenario A*	Increase Stable	No significant change in precipitation	Slight increase in productivity Slight decrease	Scenario A	Increase in productivity No change in cultivated area
		Scenario B*	Increase Stable			Scenario B	Increase in productivity Slight decrease in cultivated area
Potato	Cost of irrigation ($/ha) Agricultural export volume and value	Scenario A*	Moderate increase in cost of irrigation No change in agriculture export volume and value	Temperature increase hindering proper tuber formation and starch accumulation.	High increase in the cost of irrigation High decrease in agricultural export volume and value	Scenario A	High increase in cost of irrigation High decrease in agriculture export volume and value
		Scenario B*	Moderate increase in cost of irrigation Moderate decrease in agriculture export volume and value			Scenario B	High increase in cost of irrigation High decrease in agriculture export volume and value
Tomato	Productivity	Scenario A*	Slight increase in productivity	Decrease in water availability from decreased precipitation Temperature increase affecting yield and quality	Slight decrease	Scenario A	No change in productivity
		Scenario B*	Moderate increase in productivity			Scenario B	Slight increase in productivity
Cherry	Productivity Cultivated area	Scenario A*	Slight increase Slight increase	Chilling requirements slightly unmet and unfavorable blossom conditions due to increased temperatures	Slight decrease in productivity Slight increase in cultivated areas	Scenario A	Stable productivity Slight increase in cultivated area
		Scenario B*	Increase Stable			Scenario B	Stable productivity No change in cultivated area
Apple	Agricultural export volume and value Percent of orchards	Scenario A*	Slight decrease of export volume and value	Chilling requirements unmet and unfavorable blossom	Moderate decrease of export volume and value	Scenario A	Decrease of export volume and value Moderate increase

VULNERABLE HOTSPOTS	INDICATORS	CHANGE IN INDICATORS UNDER NON-CLIMATIC (BUSINESS-AS-USUAL) SCENARIOS		CHANGE IN CLIMATIC FACTORS	CHANGE IN INDICATORS UNDER THE CLIMATE CHANGE SCENARIO	OVERALL CHANGE IN INDICATORS	
	under drip irrigation		Slight increase in the percent of orchards under drip irrigation.	conditions due to increased temperatures Decrease in water availability for irrigation in some areas from decreased precipitation	Moderate increase in the percent of orchards under drip irrigation		in the percent of orchards under drip irrigation
		Scenario B*	Decrease of export volume and value Increase in the percent of orchards under drip irrigation.			Scenario B	High decrease export volume and value High increase in the percent of orchards under drip irrigation
Grapevine	Agricultural export volume and value	Scenario A*	Slight increase in export volume and value	Decrease in precipitation Temperature increase affecting yield and quality	Moderate decrease	Scenario A	No change in export volume and value
		Scenario B*	No change in export volume and value			Scenario B	Moderate decrease in export volume and value
Banana	Agricultural export volume and value Cultivated area	Scenario A*	Slight decrease in export volume and value No change in cultivated area	Decrease in water availability from decreased precipitation	Moderate decrease in agricultural export volume and value Moderate decrease in cultivated area.	Scenario A	High decrease in export volume and value Moderate decrease in cultivated area
		Scenario B*	Moderate decrease in export volume and value Slight decrease in cultivated area			Scenario B	High decrease in export volume and value High decrease in cultivated area
Olive	Productivity	Scenario A*	No change	Decrease in precipitation Increase in temperature Increase in relative humidity	Slight decrease	Scenario A	No change in productivity
		Scenario B*	No change			Scenario B	Slight decrease in productivity
Small ruminants	Number of heads of small ruminants (goats and sheep) Total production of milk.	Scenario A*	No change in number Slight increase in milk production	Decreased precipitation and change in rainfall patterns.	Moderate decrease in the number of small ruminants Slight decrease in the production of milk.	Scenario A	Moderate decrease in number No change in milk production

VULNERABLE HOTSPOTS	INDICATORS	CHANGE IN INDICATORS UNDER NON-CLIMATIC (BUSINESS-AS-USUAL) SCENARIOS		CHANGE IN CLIMATIC FACTORS	CHANGE IN INDICATORS UNDER THE CLIMATE CHANGE SCENARIO	OVERALL CHANGE IN INDICATORS	
		Scenario B*	Slight decrease in number Slight increase in milk production			Scenario B	High decrease in number Slight decrease in milk production

2.2. ADAPTATION MEASURES

The Lebanese agriculture sector's contribution averaged 5.8% of the national GDP between 1999 and 2007 (EAM-PCM, 2005, 2006, 2007a, 2007b, 2009). The budget of the Ministry of Agriculture has never reached beyond 3% of the governmental expenditure allocations (MoA, 2007).

Nevertheless, 27% of the country's total area is made of arable land. Forests and woodlands occupy 23% (MoA, 2007; MoA/FAO, 2005b). Rangelands include seasonal pastures, parts of forests and woodlands as well as some agricultural area, thus their area cannot be defined but roughly estimated to 50% of the country's total area.

The rural population constituted 13.4% of the total population in 2005 and is projected to decrease to 10% by 2030 (UN, 2007). Farmers counting on agriculture as a primary source of revenue constituted 2.5% the total labor force in 2005[7] (FAO, 2010). However, this segment of the society is the most vulnerable to climate change. Poverty is mostly affecting the rural population that depends on agriculture for their livelihoods.

On the other hand, Lebanon's food security balance is negative. Half of the value of food consumption is imported. Moreover, this deficit tends to increase with the increasing population.

The impact of climate change varies from one crop to another and from one region to another. Its effect on specific cultivars is rarely mentioned in the literature. Climate change, when combined with an increase in CO2 concentration in the atmosphere may lead to an increase in the yield of some crops (Pervez et al., 2009; Haverkort, 2008; Venterella, 2006). However, most researchers agree that the negative impact of climate change becomes significant in the second half of the 21st century (FAO, 2008; WB, 2009; IFPRI, 2009).

The baseline year for this assessment is 2005. Adaptation should start before 2050 in order to reduce the expected negative impacts of climate change.

Adaptation is vital not only to support the livelihood of rural populations and to sustain the viability of the agriculture sector, but also to maintain an acceptable level of food security. Adaptation measures should integrate all types of agricultural land use including arable land, woodland and rangeland, and feature within a sustainable and integrated management framework of agricultural input resources. External benefits from implementing action plans for sustainable management of forests, rangeland and arable land include a reduction of the risk of forest fires, soil erosion and land degradation and an increase in water conservation in agriculture.

The key adaptation measure for climate change is setting and implementing a sustainable agriculture policy. Adaptation measures vary horizontally according to the agricultural sub-sectors and their vulnerability to climate change. These measures vary vertically according to the different actors involved in the development and implementation of this policy.

Adaptation measures for the agriculture sector are divided into two groups (UNFCCC, 2007):

1. Field-level measures; and
2. Research, education, assistance, infrastructure, and institutional measures (UNFCCC, 2007).

7 Statistics compiled by the International Labour Organization (ILO) through household surveys for the year 2004 show that 4.65% of the labor force consists of 'skilled agricultural and fishery workers'. The FAO-reported percentage (2.5% for the year 2005) does not include fishery workers, and includes only permanent farmers.

These measures should be coherent and synergic.

The field-level measures relating to the vulnerable agricultural sub-sectors are addressed briefly within the following paragraphs. The research, education, assistance, infrastructure and institutional measures will be elaborated within a different paragraph that addresses the role of the different actors.

2.2.1. Field level measures

The vulnerable pre-selected sub-sectors consist of important perennial crops (apple, cherry, olive tree, grapevine), rainfed cereals (wheat), irrigated horticulture (potato and tomato), banana and small ruminants (goat and sheep).

Data concerning the vulnerability and impact of climate change on the yields of these crops under Mediterranean climatic conditions remains scarce if not absent. The existing references are mostly from developed countries with similar climatic conditions (i.e. California and Southwestern Australia), and to a lesser extent from Europe.

Farmers, shepherds, nursery caretakers as well as service provider enterprises (agriculture inputs companies) are the concerned stakeholders for field-level adaptation measures.

Cereals and rainfed crops

- Change planting dates, according to precipitation and temperature variations.
- Shift to less water consuming crops, e.g. barley instead of wheat, and drought- and heat-tolerant wheat cultivars. Barley is more tolerant to heat and highly demanded as a fodder crop.
- Change the cropping pattern according to precipitation isohyets. For example, in northern Bekaa, the limit of wheat and barley should change according to average annual precipitation: 400 mm/year and 250 mm/year respectively.
- Introduce new crops that are drought and heat tolerant in northern Bekaa, e.g. industrial hemp.
- Adopt sustainable agricultural practices such as conservation agriculture, organic farming, suitable crop rotations, etc.

Horticultural irrigated crops

- Change planting dates, according to temperature variation coupled with lower frost risk and lower soil moisture.
- Shift to less water consuming crops or cultivars (i.e. snake cucumber instead of cucumber, etc.), and replant the same perennial crops or varieties on drought tolerant rootstocks (especially for cucurbitaceous and solanaceous varieties.
- Shift to more heat tolerant cultivars for vulnerable crops, i.e. potato, tomato, lettuce, cabbage, etc.
- Shift the area and timing of cultivation of the crops according to irrigation water availability during the season.
- Adopt sustainable agriculture practices such as conservation agriculture, adequate crop rotations and organic farming.
- 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.
- Use mulch to reduce evaporation and weeds.
- Adopt integrated pest management techniques, when organic farming is not an option, to decrease chemical use and lower the cost of production.

- 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. Newly introduced crops should take into consideration the scarcity of irrigation water.

Specific adaptation measures for potato and tomato crops are summarized hereafter in Table 2-7.

Table 2-7 Field Level Adaptations Measures for Potatoes and Tomatoes

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. Rationalize irrigation frequency and amounts according to soil moisture and plant needs (i.e. use of tensiometer). 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. Promote conservation agriculture for potato and introduce adequate crop rotations.
Tomato	Adopt new plantation systems (new greenhouse architecture/ rootstocks/ plantation density…) to cope with rising humidity and temperatures. Implement studies for the substitution of tomato cropping by appropriate crops in the Bekaa valley, in areas where water is not available.

Perennial crops

- Substitute, through replanting or grafting, varieties that have high chilling requirements by others requiring low chilling in vulnerable areas. As mentioned earlier, the vulnerable areas are the lower limits in altitude of the area of cultivation of each crop. This measure concerns mainly apple, cherry, and to a lesser extent other stone fruits, olive and grape.
- Replace water-consuming crops with less water consuming crops. For example, plant figs instead of kaki (or persimmon), grapes instead of peaches, etc. or shift to early harvesting species and varieties with lower water demand (i.e. cherry, almond, early varieties of peach, plums and apple), as well as replanting the same perennial crops or varieties, but on drought tolerant rootstocks (e.g. almond instead of peach).

- Adopt sustainable agriculture practices such as no-till farming or conservation agriculture and organic farming.
- Shift to irrigation systems that are more efficient such as drip irrigation or sprinklers, and adjust irrigation schedules and water quantities according to the increasing crop water demand.
- Adopt integrated pest management techniques (IPM) and good agricultural practices (GAP) when organic farming is not an option, to decrease chemical use and lower the cost of production.

Specific measures for the selected vulnerable perennial crops are summarized hereafter in Table 2-8.

Table 2-8 Field Level Measures for Cherries, Apples, Grapevines and Olives

CROP	MEASURES
Cherry	Introduce eventual cultivars with low chilling requirements that are planted in other Mediterranean countries (i.e. Cristobalina, Brooks) and maintain the early local cultivars (Nouwari, Telyani) at altitudes between 1,000 and 1,300 m. Select high performing clones of Prunus mahaleb or other equivalent rootstock. Rationalize the use of irrigation water, through drip irrigation, and reduction of water consumption after harvesting (by 60% of the ETP).
Apple	Substitute cultivars with high chilling requirements with varieties requiring lower chilling (below 500 hours): Mollie's Delicious, Anna, Ein Shemer, Dorsett at altitudes below 1,200 m. Substitute standard varieties with early and late varieties with moderate chilling and water requirements: Gala, Granny Smith, Pink Lady, etc., at altitudes between 1,200 m and 1,500 m. Shift to less water consuming crops (i.e. vines, olive, plums, cut flowers). Research on products inducing bud break and blossom to substitute for chilling requirement (i.e. Thidiazuron) in years with warm winters (Austin & Hall, 2001). Introduce eventual drought and/or heat tolerant rootstocks. Rationalize the use of irrigation water through drip irrigation.
Grapevine	Conduct studies on appropriate production systems (rootstocks/ distance of plantation/ training system/ mulching…) to cope with climate change, and disseminate results to farmers. 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 results 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.

CROP	MEASURES
Olive	Study and disseminate among farmers new tree training and pruning techniques in order to reduce alternate bearing between years, in a manner that could compensate yield losses resulting from climate change.
	Disseminate IPM and biological control techniques for olive fly and olive moth.
	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

- Shift to areas where water for irrigation is available and where water salinity levels are acceptable. Rises in temperature should allow for banana plantations to grow at higher altitudes and latitudes (Implement studies for the introduction of Banana in the plain of Akkar by the middle of the century, and how to include it in crop rotations for a sustainable agriculture).
- Adopt integrated pest management and promote the use of shade nets to reduce transpiration and extreme climatic effects (hail, wind).
- Promote other tropical and subtropical crops, especially avocado varieties that are cold and drought tolerant, and new citrus cultivars.
- Expand the adoption of production systems that include greenhouses and drip irrigation systems, with adequate plantation schemes in order to reduce water consumption and cope with the increase in humidity and temperature.

Small ruminants

Rangeland in Lebanon mainly consists of seasonal pastures that depend mainly on precipitation amounts, rainfall distribution and temperature. Transhumance from one region to another is frequent. Nevertheless, few data reveals climate change effect on rangeland. If some areas may benefit from a longer grass season due to higher temperatures, less snow cover, and more rain days, others will suffer from a lack of precipitation and a shortening in the pasture season. Data concerning the actual and the potential carrying capacity of rangelands in Lebanon is lacking. Field adaptation measures should follow research results, and a national rangeland action plan, which involves institutional, infrastructure, assistance and educational measures. These field measures would include:

- 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.).
- Introducing fodder species in crop rotations, namely in conservation agriculture and in organic farming.
- 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.

2.2.2. Research, education, assistance, infrastructure, and institutional measures

Agriculture policies are the frame for all these measures. However, these policies should be addressed in such a way to deal with climate change and food security. Hence these policies should take into consideration the following points:

- The timeframe of agriculture policies is generally linked to the mandate of successive governments. This timeframe should have a longer-term vision, reaching the end of the 21st century.
- If food security is to be linked to climate change and to agriculture, it is pertinent the government should implement a nutritional or food policy that is linked to agriculture.
- For any agriculture policy to be successful, farmers' groups should be considered as the end beneficiaries and the implementing mechanism of this policy. Thus, farmers' groups should be consolidated.
- Farmers groups as well as the policy should be sub-sectoral or market chain oriented, in order to better diagnose the vulnerability, assess the measures and provide the framework for adaptation measures.

Research measures

Although agriculture research institutions and programs in Lebanon are limited, and not always cost effective, these entities should be strengthened and enhanced to elaborate research programs in fields related to adaptation to climate change. The existing governmental research institutions (LARI, NCSR) should join venture with local universities (AUB, LU, USJ, USEK, NDU, LAU, BALAMAND…) and regional institutions with long past experience in arid and semi-arid areas (ICARDA, ACSAD). Ultimately, a network of research institutions that address research on agriculture and climate change in Mediterranean countries could provide invaluable insight and direction on critical areas for action.

Some of the major issues to be addressed are:

- Conservation of agro-biodiversity by the creation of a gene bank and completion of the existing ones for species, not only those found in arid and semi-arid areas, but also under Mediterranean climates.
- Studies on the potential genetic resources that would cope with climate change, through adaptation to drought, salinity, higher temperature, lower chilling requirements, shorter vegetation period, early maturity, resistance to pests and diseases…etc., while maintaining a suitable production. The target species are wild fruit trees, wild fodder species, selected varieties of fruits and vegetables, ruminant breeds, honeybees, etc.
- Models tackling the potential agriculture production systems that could adapt to climate change such as suitable crop rotations, no-tillage agriculture, organic farming, mixed farming…etc.
- Elaborate scientific studies to assess the nutritional value and the carrying capacity of different types of rangeland (grassland, woodlands, forest understory, post-harvest agriculture land and fallow) at different climatic conditions.

- Monitor meat and milk productivity of small ruminants according to the animal pedigree, type of rangeland and climatic conditions.
- Implement research on alternative crops or green cover (drought and heat tolerant) to replace summer and autumn potato cropping in the Bekaa valley.
- Water consumption and water needs of various crops and cultivars, and their variability with climate change, agriculture production systems and regions.
- Water treatment and water recycling.
- Socio-economic models that would engage water price efficiency according to the cultivated irrigated crops, i.e., virtual water price*.
- Biotechnology.
- The impact of climate change on nutrition diversity, diet and food safety.
- Economic studies simulating the cost of adaptation for specific vulnerable agricultural sub-sectors.

Educational and assistance measures

Educational measures should be split according to the target group. Research results and technology advances from other countries should be highlighted in the curricula of the different universities that are dealing with agriculture, economics, environment and natural resources management. These results should be disseminated properly to the concerned public institutions and the private sector. Ministries, according to their respective roles, should implement awareness campaigns and capacity building to assist the following specific target groups:

- Farmers' groups, cooperatives and associations
- Agro-industrial producers
- NGOs, CBOs, municipalities
- Nutritionists and food consumers
- Water associations and water offices
- College and school students

The material to be disseminated include the research findings and other adaptation field measures, i.e. promotion of new cultivars, rootstocks, pruning and planting methods, the use of shade nets, etc., as well as the goals of the agricultural policy, such as shifting areas of production, adoption of new irrigation systems, implementing the national action plan for rangeland management, etc.

Infrastructure measures

Public institutions should rehabilitate their infrastructure to address operational inefficiencies (quarantines, laboratories, frontier posts…). Infrastructure related to the agriculture sector covers water harvesting and distribution systems, including dams, reservoirs and channels.

At the communal level, water reservoirs, channels and hill lakes should be created or rehabilitated.

However, most of the infrastructure occurs at the level of farmers. It includes hill lakes, channels, pipes, irrigation systems, as well as other agricultural infrastructure like terraces, greenhouses, agricultural machinery, agro processing plants, storage and packaging units, hives, farm constructions, etc. Nevertheless, most of the infrastructure is not relevant for adaptation measures. Only three major lines should be addressed: water harvesting and irrigation infrastructure, farm constructions and greenhouses.

- Water harvesting techniques should be promoted at all levels. If dams and reservoirs are not considered as "agricultural" installations, hill lakes and small water reservoirs at the farm level should be reinforced and subsidized by the government whenever there are opportunities to develop them. The Green Plan is the mandated authority to provide such services to farmers on a demand-driven basis.

- Irrigation systems that are water efficient such as drip irrigation, mini-sprinklers and sprinklers should be promoted and integrated within the Green Plan's activities.
- Farm constructions for poultry and animal husbandry should be restored and adapted to conditions under climate change. Thermal insulation and architectural adaptation are necessary to reduce temperature change effects inside the farm.
- Greenhouses architecture and material should be changed in order to handle rises in humidity and temperatures on the coastal zones.
- Biotechnology infrastructure for the production of F1 potato seeds, etc.

Institutional measures

The legislative framework related to agriculture and natural resources management should be reviewed and harmonized with the conventions that are ratified by the Government in relation to climate change, combating desertification, and biodiversity. National action plans should be set and implemented in the light of these conventions, on the basis of a participatory approach with local actors. The inter-linkages and conflicting mandates between different institutions should be resolved and responsibilities should be defined and distributed. The human resources and organizational structure of the Ministry of Agriculture should be reviewed according to law amendments in order to provide the desired services related to adaptation measures. The major service areas to be reinforced are:

- Natural resources management services (forestry, rangeland, water conservation)
- Research institutes as to achieve the research measures discussed earlier
- The Green Plan which would be in charge of the implementation of the infrastructural adaptation measures related to water
- Agriculture observatory that would adapt their data gathering and analysis by integrating indicators related to vulnerability, adaptation and mitigation of climate change
- Extension services to disseminate information and implement training activities at the farmers' level

Some of these major streams, namely research and extension services could be delegated or implemented in joint venture with other directorates or departments within the Ministry of Agriculture, i.e. Plant Resources, Animal Resources, etc., the private sector such as input and service providers), academia such as universities and research institutes, and NGOs.

It would be necessary to propose a funding mechanism and a climate change unit within the Ministry of Agriculture in order to implement and monitor these measures. For instance, subsidies and credit facilitation policies should be in line with the proposed adaptation measures, i.e. promoting drought tolerant crops, drip irrigation, IPM, GAP, conservation agriculture…etc. Another institutional measure will be the accreditation system for the production of F1 potato seeds, or the certification of GAP, IPM, and conservation agriculture.

COST OF ADAPTATION

Most references mention rough estimates of the cost of adaptation of the agriculture sector to climate change. However, the IPCC guidelines and methodology of estimation of this cost are not relevant for Lebanon. In Lebanon, external factors affecting eventual losses in production and quality are more significant than climate change. Among these factors are land use conversion and socio-economic changes. Besides, some adaptation measures are ongoing and implemented regardless of climate change, to improve yields and product quality, or to decrease the cost of production (i.e. modernizing greenhouses, IPM, organic farming, localized irrigation…).

Since Lebanon is already importing half of the local food needs, factors affecting food security depend more on international rise of food prices. The national economic scheme is largely reliant on the sectors of trade and services, positioning Lebanon as an economic "dependency" of the two regional major economical poles: the European Union and the Arabian Gulf States. Hence, the country's capacity to meet its food expenses from non-agricultural revenues is primarily linked to the economic situation in these two poles. Nevertheless, half of the residents' food needs are produced locally. Hence, the contribution of the agriculture sector in the economy and in food security is essential (MoE/AUB, 2009).

The cost of adaptation at farm level would be impossible to address. Field measures of adaptation are not limited in time, but are rather a continuous process. The number of exploitations and actors involved are tremendous and heterogeneous. Some measures are costless and comprise mainly operations that do not necessarily pose an additional cost for farmers. These include, for example, changing planting dates, shifting varieties, no-tillage, crop diversification, etc. Other measures require additional investments in order to cope with climate change such as irrigation systems, new rootstocks, higher plantation density, adapted green houses 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. For instance, since the mechanization depends mostly on the size of the exploitation e.g. if the irrigation system costs between 300 and 500 USD/dunum, this amount would not be proportional for large scale farms. The cost of seeders machinery in conservation agriculture is also related to the size of the farm, the type of the machine, and the manufacturing country as well. The number of plants to substitute and the cost of the new plants are also variable according to the species and the size of exploitation, as well as the origin of the plant and if it is patented or not (e.g. from 3 to 15 USD within the same species, according to the cultivar and rootstock used). Finally, most of these measures line up as mitigation measures, and their cost will be analyzed within the mitigation section.

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 cited above. The budget line of adaptation is thus included within the strategy, which means that only additional budgetary requirements should be addressed. This would mean that budget lines should account for the following:

- Natural resources management services (forestry, rangeland and water conservation)
    - Recruitment of technical engineers and forest rangers
    - Capacity building and training of staff
    - Upgrading the necessary material and infrastructure (Forest rangers' centers, GIS unit, forestry and fire fighting tools, irrigation systems for nurseries, nursery rehabilitation…)
    - Monitoring for forest, woodland and rangeland resources
    - Rangeland and water management (water harvesting, flood management…)
    - Reforestation plans
- Green Plan

  - Recruitment of engineers and technicians
  - Capacity building and training of staff
  - Converting exploitations to more water-efficient irrigation systems
  - Water harvesting techniques
  - Land reclamation and terraces maintenance
  - Agricultural roads
- Agriculture observatory
  - Capacity building and training of staff
  - Monitoring the impact of climate change on agriculture
  - Estimating vulnerability losses as well as adaptation cost
- Extension services
  - Recruitment of engineers, veterinarians and technicians
  - Capacity building and training of staff
  - Upgrading the necessary material and infrastructure (extension centers)
  - Audio-visual and media campaigns
- Research institutes (LARI/NCRS)
  - Recruitment of researchers in fields related to the impact of climate change on agriculture and adaptation measures
  - Upgrading the necessary material and infrastructure to implement research
  - Disseminating results to concerned actors

The current minister is aiming to work on most of these issues by doubling the MoA budget, and relying on few projects with the European Commission, FAO, UNDP and GTZ. The minister is also aiming at providing credits from local banks for farmers, but budgets for all of the above were not announced at the time of repot writing.

As mentioned above, research institutes and extension service could work in joint venture with the private sector, academia, NGOs and international organizations or institutions. Such multi-party approaches would minimize governmental expenses and enhance the contribution of the private sector.

Other stakeholders, such as the agriculture observatory, the Green Plan and different directorates within the Ministry of Agriculture, and other line ministries, are already being funded to implement projects and activities that would fall under the adaptation or mitigation of climate change impact. It would be pertinent to keep supporting such collaborations by an adequate funding mechanism. Otherwise, different ministries should take into account the necessary budget in order to keep these projects sustainable into broader programs.

The recommended adaptation measures are elaborated into adaptation strategies in Table 2-9. It should be noted that the indicative budget is a rough estimate based on professional judgment, and sometimes reflects the cost of studies needed to be carried out prior to the implementation of the proposed activities. In many instances, only the material cost is indicated; technical assistance and managerial cost are not included, however they should not exceed 30% of the material value. Each of the mentioned activities requires an in-depth assessment to determine its actual cost at the time of planning and implementation.

Table 2-9 Adaptation Action Plan for the Agriculture Sector

IMPACT	PROPOSED ADAPTATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/MT/LT) *	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
Reduction of water availability for irrigation	Shifting from surface to drip irrigation	▪ Survey on water sources ▪ Topology-hydrology-water needs study ▪ Design of irrigation schemes ▪ Installation of systems ▪ Training for farmers	▪ Farmers/COOPs ▪ Water Users' Associations ▪ Municipalities ▪ Municipality unions ▪ Private sector (study/implementation)	ST	5000$/ha; technical assistance and managerial costs excluded	Farmers, municipalities, municipality unions, water users' associations, Green Plan, MoEW, CDR
Increase in pest outbreaks	Adopting Integrated Pest Management (IPM) or organic farming	▪ Assess the cropping pattern of the concerned areas, define the key pests and diseases that are a major problem ▪ Define the number of traps, pheromones to be distributed as well as the closest meteorological station to be linked to import the required material ▪ Distribute the necessary material (traps, pheromones…) ▪ Training for farmers and installation of material	▪ -Farmers/COOPs ▪ MoA (extension/ implementation) ▪ LARI (technical assistance) ▪ Local NGOs (assistance/ implementation) ▪ Private agriculture enterprises (material import)	ST	100$/ha; technical assistance and managerial costs excluded	Farmers, MoA, FAO, NGOs…
Chilling requirements not met for some cultivars at specific locations, and rootstocks not tolerating drought	Renovating orchards with low chilling requiring cultivars grafted on drought tolerant rootstocks	▪ Survey on cropping pattern (cultivar/ rootstock) per altitude ▪ Identify vulnerable orchards and quantify trees to be replaced ▪ Propose a plan of orchard renovation with adapted cultivars and rootstocks ▪ Renovate orchards with a rate of 20% of trees over 5 years ▪ Training farmers on new	▪ Farmers/COOPs ▪ MoA (planning/ extension) ▪ LARI (seedling quality control/technical assistance) ▪ ACSAD, Universities (research/assistance) ▪ Local NGOs (technical assistance) ▪ Nurserymen (local providers) ▪ Private agriculture	LT	3500-15000$/ha according to plant material source and plantation density. Technical assistance and managerial costs excluded.	Farmers, FAO, NGOs…

IMPACT	PROPOSED ADAPTATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/MT/LT) *	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
		plantations management	enterprises (technical assistance/ plant importers)			
Increase in water demand in annual plants with low tolerance to higher temperatures	Shifting in planting date Shifting to adapted cultivars Shifting to conservation agriculture	▪ Conduct trials for new cultivars and plantation systems ▪ Conservation agriculture for potato, cereals and tomato ▪ Disseminate results to engineers (public/private) ▪ Propose Good Agricultural Practices (GAP) to concerned farmers ▪ Import necessary plant material and equipment ▪ Select appropriate cultivation dates for each crop ▪ Develop a system to alert farmers on the occurrence of extreme weather events (early hail, frost, etc.)	▪ Farmers/COOPs ▪ MoA (extension/ assistance) ▪ LARI, Universities, ICARDA, ACSAD (technical assistance/ research) ▪ CODEL (GTZ): (research/assistance) ▪ Agriculture enterprises (material importers/ assistance)	MT	100-1000$/ha according to technique and practice. Large equipment (seeders), technical assistance and managerial cost are excluded	FAO, farmers, NGOs…

N.B: adaptation measures for rangeland are included within the herbaceous ecosystems in the biodiversity chapter.

* ST = Short-term

MT = Medium-term

LT = Long-term

2.3. RECOMMENDATIONS FOR FURTHER WORK

This report enabled us to identify several gaps related to the assessment of vulnerability and impact of climate change on agricultural crops. For instance, linking the production, yields and quality of fresh products to climate is crucial in agriculture census and data gathering and reporting. This will help as well in defining key parameters to be measured and monitored to assess climate change and vulnerability, and consequently to estimate adaptation needs and potential. Research should address climatic and biological parameters that are related to climate change (e.g. number of chilling hours required for local fruit tree cultivars, etc.).

Finally, a more accurate climatic simulation model that takes into consideration topography, the effect of distance from the sea and altitude is needed to better simulate changes according to the Lebanese context. A more exhaustive application of GIS techniques would be also valuable to better determine the vulnerability and impact of climate change and adaptation of the agricultural components in Lebanon.

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