Journal of Arid Environments 56 (2004) 659–680

Journal of Arid Environments

www.elsevier.com/locate/jnlabr/yjare

Combating desertification in the Negev: dryland agriculture vs. dryland urbanization

B.A. Portnov[a,*,1], U.N. Safriel[b,1]

[a] *Department of Natural Resources and Environmental Management, Haifa University, Haifa 31905, Israel*
[b] *Department of Evolution, Ecology and Systematics, Hebrew University of Jerusalem, Jerusalem 91904, Israel*

Received 1 October 2002; received in revised form 22 April 2003; accepted 6 May 2003

Abstract

The Negev region occupies nearly two-third of Israel's land area (21,671 km^2) but hosts less than 9% of its 6.5 million strong population. Until recently, the process of desertification did not affect the Negev profoundly. This was mainly due to large-scale afforestation programs, restrictions imposed on grazing, and large water subsidies from the less arid part of the country to its more arid part. However, there are some indications that the process of desertification in the Negev has already started and may accelerate in the future. In light of this trend, the efficient long-term strategy for the Negev's development is essential. The present study compares two alternative strategies of the Negev's future development: agricultural expansion vs. urbanization path. Two basic criteria—the minimization of adverse environmental impacts and economic feasibility—are used for the evaluation. The urbanization path is found to be preferable. Since agriculture and livestock grazing are the major contributors to desertification, replacing them with urban development may lessen the risk of desertification in the future. In contrast, urban development, if properly planned and regulated, may reduce the spatial extent of the area affected by agricultural development, and thus minimize the anthropogenic impact on the desert environment. Economic reason is also important: While even in the future, agricultural production in the Negev may remain limited due to economic considerations, urban development may justify the often-large investment required for the provision of fresh water.

Keywords: Drylands; Desertification; Urbanization; Agricultural development

*Corresponding author. Fax.: +972-4-824-9971.
E-mail address: portnov@nrem.haifa.ac.il (B.A. Portnov).
[1] Both authors are former members of J. Blaustein Institute for Desert Research.

0140-1963/03/$ - see front matter
doi:10.1016/S0140-1963(03)00087-9

1. Introduction

Most Mediterranean countries contain a diversity of land types, of various degrees of aridity and soil fertility. In the southern Mediterranean coastal areas are usually less dry and more fertile than inland regions, many of which are semi-arid and arid deserts; the southern regions of several northern Mediterranean countries are drylands, e.g. Spain, Italy and Greece (Middleton and Thomas, 1997). In the least dry and the most fertile parts of these countries land is used for agriculture, industry and urban settlement.

With the surge of population increase recently experienced by the Mediterranean basin, competition on land between agriculture and industry on the one hand, and urbanization on the other hand intensifies. In Israel, where there is a north–south gradient of aridity (the north and centre are dry sub-humid, whereas the south is semi-arid, arid, and hyperarid), recent and intensifying urbanization out-competes agriculture and industry. As a result, agriculture and polluting industries are pushed from fertile land to the semi-arid northern Negev, or even to the arid and hyperarid, central and southern Negev, respectively.

In the Mediterranean, as in many other countries, agriculture and heavy industries are nearly always the main causes of desertification: land degradation due to soil erosion, soil and water salinization, and loss of biodiversity. In Israel, population and urbanization pressure in the least dry drylands, is thus putting the more dry drylands at risk of further desertification. These processes are bound to intensify in Israel, and probably also in many other Mediterranean countries.

The first victim of desertification caused by agriculture is agriculture itself. As a result, dryland agriculture is often abandoned, leaving behind an ecosystem that ceased to provide environmental services, and is costly or even impossible to rehabilitate. Hence, by pushing agriculture from non-desert to desert, not only agriculture itself may be doomed, but also alternative uses of the desert, such as controlled grazing, conservation of biodiversity, recreation, eco-tourism and tourism, are excluded.

Thus, urbanization trends in non-desert drylands and other lands not only bring desertification to more arid drylands, but also deny from a country's non-desert population the use of these drylands as a resource for recreation and for alternative income-generating livelihoods. Furthermore, due to a sustained accelerated population growth, urbanization will eventually reach also the desert, but will then find there a further desertified, less hospitable environment than would have otherwise be.

In this paper, we propose an *alternative scenario* for sustainable development of a Mediterranean country having both desert and non-desert regions. Rather than concentrating now on further urbanizing the fertile an already heavily populated regions and as a result introducing more agriculture and polluting industry to the desert, we propose either full or partial cessation of the urbanization process in the fertile, heavy populated areas, and, instead of introducing agriculture to deserts, introduce urbanization to desert regions.

The present paper attempts to answer the following questions:

- What are the main development alternatives available for the Negev?
- How can desirable types of development in the Negev be encouraged?

The paper starts with a brief overview of environmental conditions in the Negev. Then it outlines both current and prospective desertification trends in the region. Following the introduction, two alternative strategies of the Negev development—agricultural vs. urban development path—are introduced and discussed in some detail. As argued, the process of desert urbanization requires special design and planning features that may make it viable. Such features (e.g. critical mass (CM), territorial contiguity, provision of unique urban functions and climate-responsive urban environment) will also be elaborated in the paper. The critical feature of desert urbanization is its land-use efficiency. As a result, large desert areas, lying outside small pockets of urban development, will become available for environmentally compatible uses, such as tourism and recreation, while agriculture will, as much as economically required, be confined to lands naturally more fertile than desert lands.

2. Negev—climate and environment

Geographically, the Negev region extends over three out of five Israel's climatic zones—semi-arid, arid and hyperarid (BIDR, 2000):[2]

- *Semi-arid zone* lies north of Be'er Sheva, the major urban centre of the region; this zone includes the northern Negev, the upper reaches of the Judean Desert, the northern Jordan Valley, the Hula Valley and the Sea of Galilee (*Kinnerot*) region. The mean annual precipitation (P) in this zone is 300–500 mm, while its mean annual evapo-transpiration (EP) ranges from 1500 to 1700 mm. The aridity index ($AI = P/EP$) for the area thus reaches 0.20–0.35. The region is characterized by a typical Asian (Irano-Turanian) biota, mixed with both Mediterranean and Sahara–Arabian desert elements.
- *Arid zone* is located south and east of the semi-arid zone, south of Be'er Sheva to Mitzpe Ramon, and east to the lower reaches of the Jordan Valley. The area is known as the central *Negev* (*dry*, in English). The mean annual precipitation in the region does not exceed 100–300 mm, while the mean annual evapo-transpiration ranges from 1700 to 1800 mm ($AI = 0.05-0.20$). The region is characterized by a typical Saharo-Arabian desert biota, mixed with Asian and Mediterranean elements, especially in its northern and higher-elevation sections.
- *Hyperarid zone* is located south and east of the arid zone. It includes the central and southern Negev, from Mitzpe Ramon to Eilat, the Dead Sea Basin and the Arava Valley. The mean annual precipitation in this zone does not exceed

[2] Two other climatic zones, located outside the Negev, are: (a) *Mediterranean dry sub-humid zone*, which stretches along the Mediterranean plain, and encompasses the valleys north of Haifa and the Galilee, and (b) Humid zone, represented by a small enclave of high-elevated areas in northern Israel.

30–90 mm, and the mean annual evapo-transpiration ranges between 1800 and 2800 mm (AI < 0.05). The hyperarid region is of a typical Saharo-Arabian desert, with an *acacia* savannah in the Arava Valley (Fig. 1).

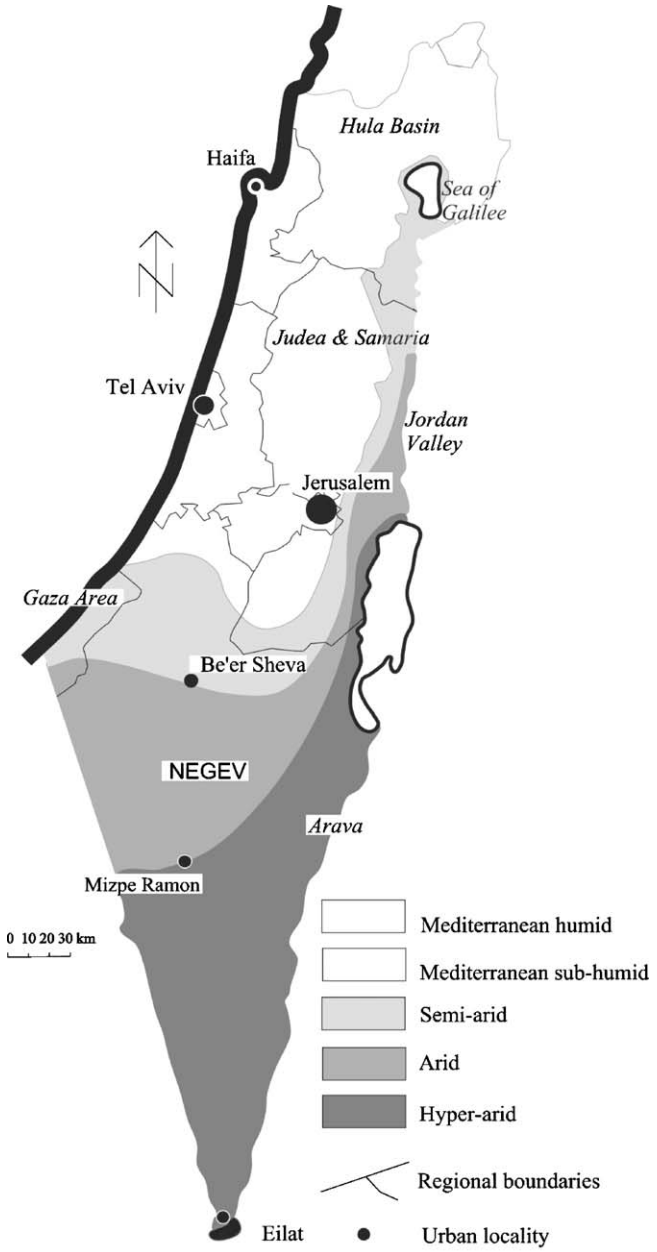

Fig. 1. Climatic zones and administrative districts of Israel.

The climate of the Negev is hot and dry during the summer, and cool during the winter. In summer daily average temperatures range between 17°C and 33°C in July and August, but maxima of 42–43°C occur in May and June, during hot waves called *sharav* in Hebrew. Relative humidity during the hot hours of the day is usually 25–30%, and as low as 5–15% during the 'sharav' waves. Winter temperatures in the Negev range between 5°C and 15°C, but temperatures near the ground surface may drop below 0°C.

Winds in the Negev are north and north-westerly in the early afternoon and evening hours, whereas at night and early morning they may turn north-east to south-east. Average maximum speeds range between 40 km/h in winter and 30 km/h in summer (absolute maxima above 100 km/h have been registered). Daily global radiation in June is about 680 Cal/cm^2/day (Etzion et al., 2001).

Rainfall in the Negev occurs only in winter, and varies annually. In the central Negev, for instance, the amount of rainfall varies annually from 20 to 160 mm (Bitan and Rubin, 1991).

3. Development patterns

Until the establishment of the State of Israel in 1948, mainly nomadic Bedouin tribes inhabited the semi-arid and arid parts of the Negev. The Bedouins, whose number did not exceed at that time some 15,000 people (ICBS, 1996–2001), were spread over an area of about 10,000 km^2.

Originally, the Bedouins subsisted on sheep, goat and camel herding. However, in the middle 19th century, they also initiated patchwork farming in *wadis* [3] that had previously been used exclusively as rangeland, and grew cereals through dry farming, often as a cash crop (Kressel et al., 1991; Abu-Rabia, 1994). In rainy years they also cropped in the late winter and spring on the area of up to 2500 km^2, reducing it to 600 km^2 in dry years (Porat, 1996).

In the pre-state period, some 20 Jewish agricultural communities (*moshavim* and *kibbutzim*) were established in the Negev. By 1948, their population grew to some 6000 residents (ICBS, 1996–2001). After the establishment of the State in 1948, an intensive urban development of the region has been initiated. The foundation of new towns in the Negev stemmed primarily from ideological and geo-political considerations:

- Establishing a national presence and sovereignty over the territory of the Negev, which constitutes nearly two-thirds of the land area of the country (Gradus and Stern, 1980).
- Re-establishing the nation's ties with its land (Drabkin-Darin, 1957);
- Re-distributing population from congested central regions to sparsely populated peripheral areas, stemmed from security and environmental considerations (Barkai, 1980).
- Accelerating the process of new immigrants' integration into the host society in multi-cultural and socially diverse new towns in peripheral areas (Golany, 1979; Kipnis, 1989).

[3] *Wadi* is a dry valley with rainfall-dependent surface run-off.

Given these considerations, urban development in the Negev led to the establishment of a number of new settlements scattered across the area at varying distances from each other. In this fashion, seven new 'development towns'—Arad, Dimona, Mitzpe-Ramon, Netivot, Ofaqim, Sderot and Yeroham—were established in the 1950s and early 1960s, while the existing towns of Be'er Sheva and Eilat received a significant growth impetus (Portnov and Erell, 1998).

The initial growth of these towns was sustained by the involuntary location of new immigrants and direct government investment in their economy (Fialkoff, 1992). Since the early 1970s, this policy was gradually replaced by various incentives designed to encourage both inward migration and private investment; these incentives included such measures as government loan guarantees, tax exemptions, and the provision of public housing (Lipshitz, 1997).

In the late 1960s, the first permanent urban settlement for the Negev Bedouins—*Tel Sheva*—was established. This attempt to encourage the sedentarization of the Negev nomads was soon found to be a failure on a number of accounts. The small houses offered in Tel Sheva were unsuited to the large Bedouin families; the high density of the town itself stood in conflict with the Bedouins' daily needs. Lastly, the use of the single type of house for construction could not address the differences in the family size, social ambitions, and financial means of Bedouin families (Ben-David, 1993; Gradus, 1999, 332pp.). These planning mistakes were corrected during the 1970s–1980s, when six new Bedouin townships—*Rahat, Kuseifa, Aro'er, Lakiya, Houra* and *Segev Shalom*—were established. In these towns, the physical layout was set as to accommodate the tribal structure, allowing for a tribal territoriality (ibid.).

Currently, there are 15 towns and cities in the Negev. They occupy less than 0.6% of its land area but concentrate more than 90% of the region's population (Table 1). The rest of the region is used for military training areas and installations, nature reserves and national parks, agriculture and industrial sites.

4. Desertification processes in the Negev

By the end of the 19th century, desertification in the drylands of Israel was most likely to result in soil salinization in irrigated dry sub-humid areas, and definite loss of natural vegetation and soil erosion in dry sub-humid and some semi-arid areas. In both sub-humid and arid parts of Israel, ecological and hydrological processes might have been disrupted. This resulted in an overall decline in productivity of the regional ecosystem. It is not clear whether or not the southern *arid parts* of the Negev had been desertified by the end of the 19th century. However, historical studies of traditional pastoralism in the Negev indicated that the existing rangelands in the region seemed to be stable at a low-level equilibrium state (Zeligman and Pervolotsky, 1994).

Until 1948, only Bedouin pastoralists inhabited the hyperarid areas of the Negev. Since they move across the region sporadically and were not sedentarized, it is unlikely that hyperarid part of the Negev was ever overgrazed. Development was introduced to these areas only after 1948. Therefore, the hyperarid part of the Negev

Table 1
Urban sites in the Negev

Locality	Area under jurisdiction in dunams[a]	Urban area in dunams (estimate)	Population in 1983	Population in 1995	Annual population growth (%)
Be'er Sheva	54,454	26,000	110,100	150,040	3.02
Ofaqim	9545	4898	12,665	20,740	5.31
Elat	58,103	7677	18,725	32,510	6.13
Dimona	30,539	7332	26,815	31,050	1.32
Yeroham	34,099	1822	6225	7715	1.99
Lahavim	960	588	NA	2490	NA
Metar	8262	1102	NA	4670	NA
Mitzpe Ramon	645,001	1005	2945	4255	3.71
Netivot	5695	3540	7755	14,990	7.77
Omer	12,773	1337	4500	5660	2.15
Arad	75,934	4786	12,560	20,265	5.11
Rahat	8851	5207	9970	22,050	10.10
Tel Sheva	4762	1474	2485	6240	12.59
Qiryat Gat	8440	10,320	25,825	43,700	5.77
Sderot	4302	3943	9060	16,695	7.02
Total:	961,720	81,031	249,630	385,065	4.45
Be'er Sheva sub-district	12,946,000	12,946,000	275,000	418,900	4.36
Urban areas, %	7.43	0.63	90.77	91.45	

Compiled from: ICBS (1996–2001) and NCRD (1998).
[a] 1 dunam = 1000 m^2.

was unlikely to be desertified by human activity prior to the establishment of the State.

During the first decades of the statehood, water conservation policies and afforestation projects appeared to have rehabilitated many previously desertified areas and prevented further desertification. However, in recent decades, signs of emerging desertification and of future potential risks have been detected.

In the dry sub-humid areas there is soil salinization due to irrigation in dry sub-humid valleys, and increasing impenetrability of dry sub-humid woodland and 'bush encroachment' leading to degraded range quality on the one hand, and woodland fires leading to soil erosion on the other hand. In the semi-arid areas, there are indications of sheet soil erosion on irrigated agricultural land, and of highly intensified gully erosion, both in regions of agricultural activity and of grazing activity.

5. Current practices of combating desertification

The process of combating desertification in the Negev and other drylands of Israel includes four major components: (a) control of scrubland grazing, (b) afforestation programs, (c) water transportation, and (d) increasing the efficiency of water use in agriculture.

5.1. Control of scrubland grazing

To reduce overgrazing in the dry sub-humid areas, mainly by goats feeding on scrubland, the 'Black Goat Law' (The Law for Vegetation Protection (by Goat Damages)) was enacted in 1950. Prior to 1948, the number of goats in the region was estimated at 185,000. By 1950, this number dropped to 71,000, which reduced the pressure on the natural scrubland. As a result, the latter rapidly developed into typical eastern Mediterranean woodlands.

Subsequently, the number of goats kept in the Negev increased to 115,000 by 1973; it went down to 70,000 (1994) and then again increased to 74,000 in 1998 (ICBS, 1996–2001). The overall positive effects of the reduced grazing pressure demonstrates the high resilience of the dry sub-humid Mediterranean woodland ecosystems, attributed to the long co-evolution of these systems with human-induced disturbances, including livestock grazing (Pervolotsky and Zeligmann, 1993; Pervolotsky, 1995).

5.2. Afforestation programs

The afforestation programs in Israel fall under three laws: 'The Forest Law', 'The City Building Directive', and 'The National Parks and Nature Reserves Law'. In 1961, the State of Israel contracted the Jewish National Fund (JNF), a national non-governmental organization, to carry out afforestation activities in Israel. By 1993, JNF planted over 200 million trees (around two-thirds of which were *Aleppo* pines), divided between 280 afforestation plots. By 1993 these plots covered 690 km^2 (or 5% of the total area of the Negev). By 1999, the size of these plots increased to 911 km^2, or to 7% (ICBS, 1996–2001).

The 22nd Country Master Plan is the National Master plan for Forests and Afforestation for the coming 25 years. During this period the amount of afforested and managed woodlands in Israel will increase to 1606 km^2 (15% of the country's dry sub-humid and semi-arid lands). JNF instituted a 'watchdog system' for identifying development plans that are incompatible with the Master plan, so that timely counter measures can be taken.

5.3. Water importation

Transforming rangeland and rain-fed cropland to irrigated croplands on a large-scale requires the planning and execution of large-scale water transportation projects. The first project of this kind was 66 in diameter pipeline drawing water from the Yarkon River in the centre of Israel to the Negev; it covered a distance of some 130 km. The annual output of this water pipe was about 100 million m^3 of water. The second large-scale project was the National Water Carrier completed by 1964. This carrier is a combination of underground pipelines, open canals, interim reservoirs and tunnels supplying about 400 million m^3 annually. Via this system, water from the *Lake Kinneret* (the Sea of Galilee) in the north of the country, located about 220 m below sea level, is pumped to an elevation of about 152 m above sea level. From this

height the water flows by gravitation to the coastal region, where it is pumped to the Negev.

These water transportation projects are accompanied by the exploitation of ground-water and of flash-floods; currently, 115 dams and reservoirs with total capacity of 100 million m^3 are constructed. In addition, Israel operates 30 desalination facilities, in which Israel's National Water Company, *Mekorot*, desalinated 9.8 million m^3 of water annually, much of it for domestic use, especially in the far south, which is out of reach of the National Water Carrier.

In spite of the water scarcity, water consumption in Israel in general and in the Negev in particular constantly rises, due to both a rapid growth of the country's population (some 2.4–2.6% per annum) and the increasing standards of living (ICBS, 1996–2001). Thus, between 1991 and 1998, per capita water consumption in Israel increased by some 26.5%, from 87.9 to 111.2 m^3. In absolute terms, the growth was even more dramatic: from 444.8 million m^3 in 1991 to 671.7 million m^3 in 1999, or more than 50% (WRI, 2001).

Different countrywide campaigns have been undertaken to promote the conservation of water resources: cotton plantations were almost totally banned some 15 years ago, heavy restrictions were imposed on private swimming pools, and watering lawns during day hours has been forbidden (Knesset, 2002); occasional cuts in water allocations for agriculture are also periodically announced (Israel Ministry of Agriculture, 2003).

However, the effect of these water-saving measures is largely offset by a rapid growth of low-rise housing and increasing number of private gardens. Investment in public infrastructure has been also on the rise (ICBS, 1996–2001), resulting in a gradual increase in water consumption in the Arab sector, among the sedentarizing Bedouin nomads, as well as in the remote Negev localities that had to limit their needs in the past to the little water that was locally available.

5.4. *Increasing the efficiency of water use in agriculture*

Prior to 1948, crops in the Negev were irrigated by surface (flood and furrow) irrigation. However, the settlers, engaged in farming in the dry sub-humid and semi-arid parts of the region, fast realized that economically viable agriculture is constrained by both the scarcity of water and the uncertainty of its supply. This recognition resulted in attempts to drill wells and draw underground water. However, the quantities obtained were quite small, and the salinity of water was often too high for agricultural use. Therefore, sprinkler and drip irrigation substituted the wasteful surface flooding practices.

Water use efficiency, which is the ratio between the amount of water taken up by the plant and the total amount of water applied, increased considerably. (The efficiency of water use is about 45% in surface irrigation and 75% in sprinkler irrigation, in drip irrigation it is about 95%.) Outdoor computers that control drip irrigation and fertigation have improved the water use efficiency even further. The increase in the water use efficiency not only helps to reduce the risks of soil salinization but also enables the transformation of much of Israel's lands of

agricultural potential from rangeland or rain-fed cropland to year-round irrigated fields and orchards.

Protected agriculture, based on greenhouses, is another common solution. In a dryland greenhouse evapo-transpiration is minimized, but cooling in summers and in some drylands warming in winter nights, are required. Technologies related to protected agriculture in Israel include the synthetic fabrics, cooling and warming devices and mechanisms, drip irrigation and fertigation, growth substrates, and supplies of insect pollinators. Either fully closed chambers or partly opened at prescribed seasons and times of day, dryland greenhouses can be fertilized with CO_2 and be protected from insects, thus reducing the use of insecticides.

Agricultural production in the Negev greenhouses is very intensive, with very high water and soil/space-use efficiency. Hydro-geological surveys have revealed that the Negev and the Arava valley possess considerable reserves, mostly fossil, of saline underground water with a variable concentration of salts. Some of the cash crops, bred for salt tolerance (especially tomatoes, melons and grapes), are of higher quality (sweeter and firmer fruit) when irrigated by brackish, rather than by low-salinity water. Their quality and out-of-season availability makes them ideal for export.

6. Prospects of future development

In coming years, the development pressure on the Negev may intensify due to a number of factors. They include: the growing shortage of land for new development in central regions of the country; improvement in the means of transportation (both water and thoroughfare); and new knowledge about desert climate, which indicates its suitability for asthmatics, arthritics and other health-risk groups (Fig. 2).

The availability of land resources in the Negev is especially significant in the local context. Israel is a small country (21,671 km^2), whose population is concentrated predominantly along the Mediterranean coast, in close proximity to its two major cities—Tel Aviv and Haifa (Fig. 1). The population of these cities and their immediate hinterland (the Tel Aviv, Central, Haifa districts) amounts to some 3.4 million residents, or nearly 55% of the country's population (ICBS, 1996–2001).

In the past decades, the most intensive population growth has occurred around these population centres. In the Tel Aviv district, for instance, the population density in 1948–2000 grew, on the average, by some 95 persons per km^2 per year (Fig. 3), from 1800 residents per km^2 in 1948 to 6750 residents per km^2 in 2000.

Unsurprisingly, urbanization in the central, sub-humid regions of Israel occurs at the expense of agricultural land. In past decades, such land has become a prime target for real-estate development (Lipkis-Beck, 1997). In turn, this process 'pushes' agriculture elsewhere, primarily to the northern border of the Negev region.

In view of this trend, there may be two alternative strategies of the Negev development:

(a) *Agricultural path:* Urbanization in the 'core' regions of Israel continues at the current rate, leading to a step-by-step transfer of agriculture and other land

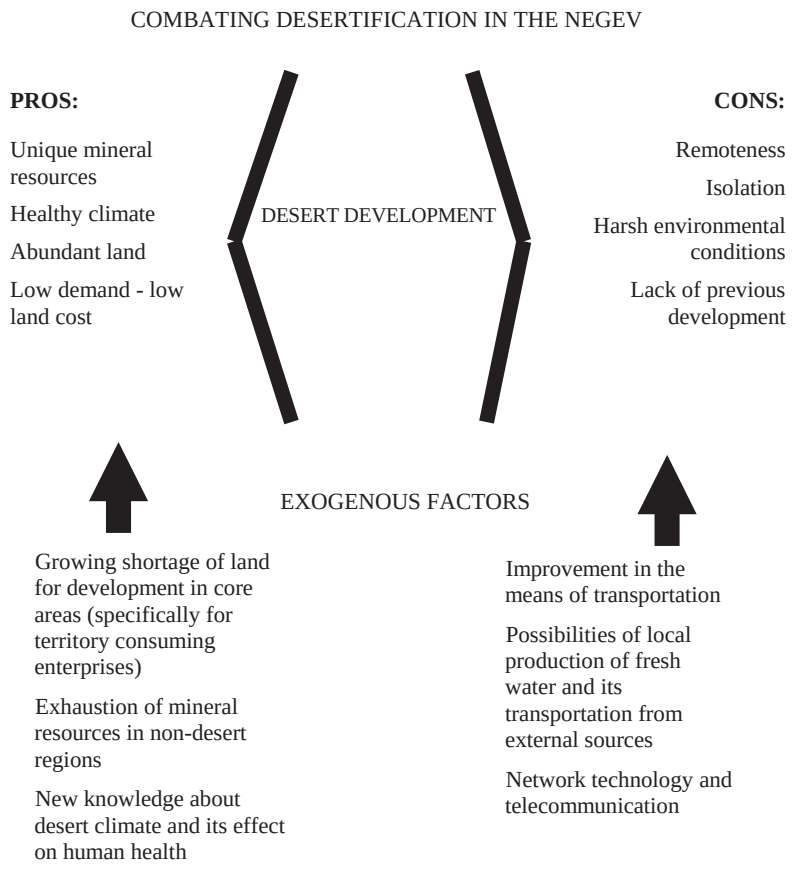

Fig. 2. Factors affecting development of desert regions.

extensive functions (such as industrial waste dumps, military installations and primary industries) towards the country's desert fringe.

(b) *Urban path:* Restriction on further urban growth in the central, sub-humid regions of the country and the concentration of such growth in the Negev drylands.

In the following subsections, we shall consider each of these development alternatives in some detail. For their comparison, we shall use two basic criteria: economic feasibility and likely long-term environmental impacts. We shall only highlight probable consequences of these scenarios, leaving their formal quantitative evaluation to future studies.

6.1. Agricultural path

The recently adopted State Master Plan of Israel—'TAMA-35'—introduces the concept of 'concentrated dispersion.' According to this concept further development

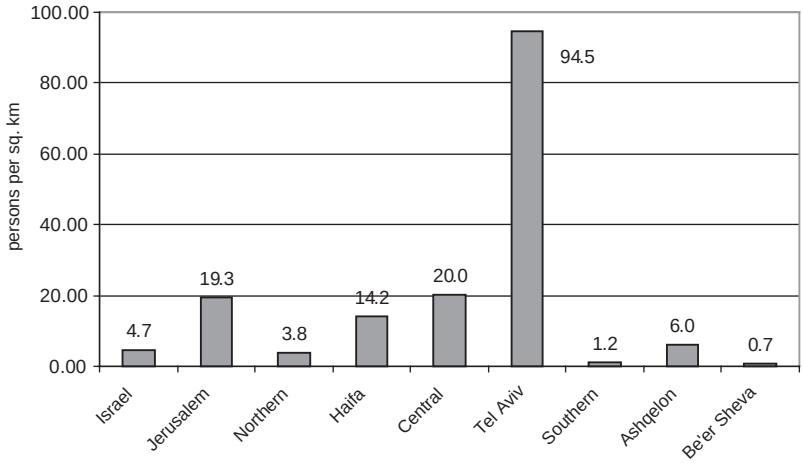

Fig. 3. Average annual increase in population density (persons per km^2) by district of Israel in 1948–1995. Between 1948 and 1995, the most substantial increase in population density occurred in the centrally located districts of the country—Tel Aviv, Central, Jerusalem and Haifa. Concurrently, in the Negev (the Be'er Sheva sub-district), the increase of population density was rather marginal—less than one person per km^2 per year. As land resources for new development in the central part of the country rapidly diminish the development pressure on the Negev is expected to increase.

should be dispersed in the national level and concentrated at the level of individual regions. In line with this concept, the plan puts emphasis on the continuing growth of four existing metropolitan centres—Tel Aviv, Jerusalem, Haifa and Be'er Sheva. Three of these metropolitan areas (excluding Be'er Sheva) are located in the central part of the country. Therefore, their expansion will cause the further concentration of development in the central part of the country. In turn, it would accelerate the relocation of non-urban functions, currently surrounding these urban centres (specifically agriculture), into peripheral locations, such as the semi-arid and arid parts of the Negev.

Is the agricultural path a viable option for the Negev? The answer to this question is rather negative. There are both ecological and economic considerations.

As Middleton and Thomas (1997) notes, agriculture-related activities (the removal of natural vegetation, overgrazing and other agricultural activities) are the major causes of desertification. According to FAO's estimates (FAO/AGL, 2000), agricultural activities are responsible for up to 30–35% of land degradation in the Middle East. The soil loss due to agricultural activities is especially evident in countries with low amount of arable land, such as Iraq, Morocco, Syria and Tunisia (Fig. 4).

Although in Israel agriculture is based on advanced technologies (such as sprinkler and drip irrigation), large-scale agriculture production in this arid region will most definitely increase the risks of soil salinization and soil erosion.

The consumption of fresh water and economic capacity of agriculture are two other important factors. In Israel, agriculture consumes annually about 60% of the

national water supply, while it contributes to only 2.4% of the national GDP. In contrast, the urban sector consumes annually 40% of the national water supply, whereas it generates 97.6% of the national GDP (ICBS, 1996–2001; MFA, 2001).

In most parts of the Negev, the economic capacity of agricultural production is lower than the national average. This is both due to relative remoteness of the region, poor soil quality, higher than average water consumption due to high evapotranspiration. Thus, according to the results of the 1995 Agricultural Survey of Israel (ICBS, 1996–2001), agricultural production in the central Negev (Region 6-South) is the least efficient among the country's agricultural regions, both in terms of output per dunam and gross value added (Fig. 5).

One comment is important. The Eastern valleys and the Arava region (Region 4; Fig. 5) represent a notable exemption from the general trend. Agricultural production in these regions is of high efficiency. There are a number of explanations to this phenomenon. First, agricultural production in the Arava is highly intensive due to a common use of greenhouses. Therefore, production per dunam is high, compared to agricultural production elsewhere. Second, the Arava region has a rich fossil reservoir of brackish water, but the risk of soil salinization due to the use of this water for irrigation is reduced—in many greenhouses crops are not grown directly on the soil but on tables with artificial substrates. Lastly, winters in the region are relatively warm, and this creates a comparative advantage in seasonal production of exported cash crops.

Another drawback of introducing a large-scale agricultural development to the Negev is its negative environmental consequences. The agriculture brought to the

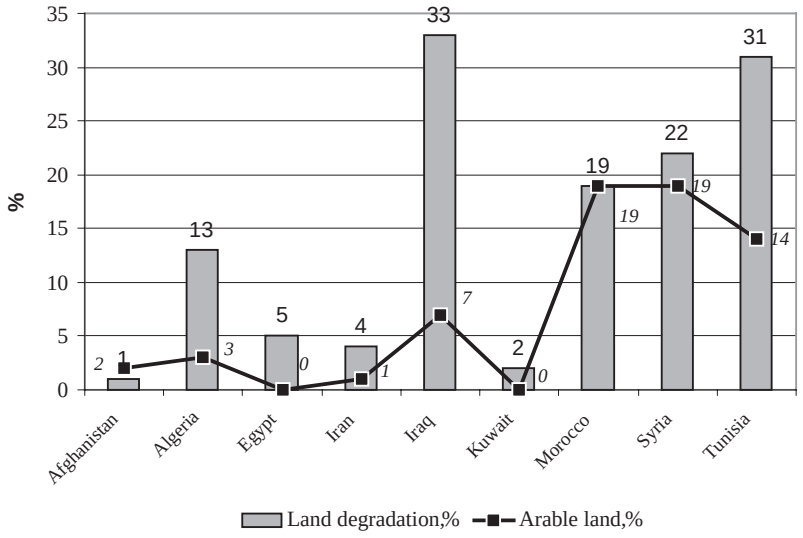

Fig. 4. Land degradation due to agricultural activities in selected countries of the Middle East. Compiled from: Terrastat—Land Resource Potential and Constraints Statistics (FAO/AGL, 2000).

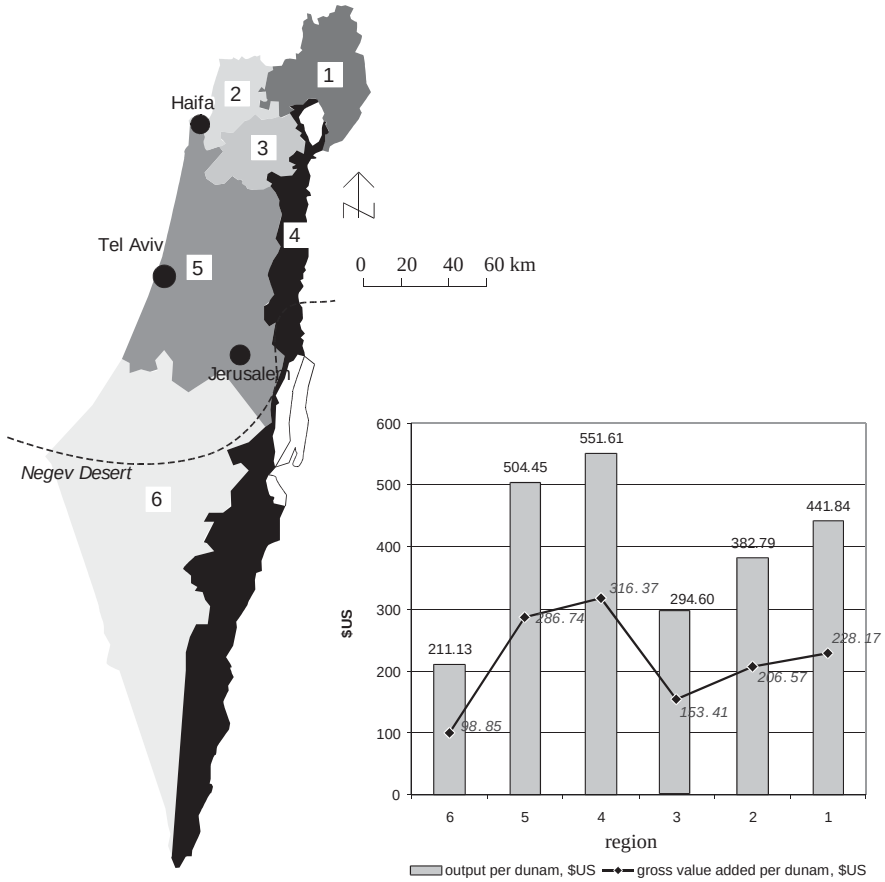

Fig. 5. Efficiency of agricultural production by agricultural region of Israel. Compiled from: 1995 Agricultural Survey of Israel (ICBS, 1996–2001). (1) Golan and Eastern Galilee; (2) West Galilee; (3) Lower Galilee and Yizre'el Valley; (4) Eastern Valleys and Arava; (5) Centre; and (6) south.

Negev will likely be based on treated wastewater that will not be desalinized, and hence it will pose a risk of salinizing the soil, which, in the long run, will reduce productivity. Thus, agriculture that is already not economically viable, may become even less viable, and will also damage, perhaps irreversibly, the ability of the environment to provide ecological services.

6.2. *Urban dispersion path*

Compared to agricultural development, the adverse effect of urban development on the desert environment may be limited. The reason is rather simple: geographically, urban development is compact. As Table 1 shows, all the urban settlements in the Negev occupy less than 0.6% of its land area, while house more

than 95% of the region's population. The concentrated urban development may thus be least damaging for the desert ecosystems, and compared to the agricultural path, may thus have less severe desertification consequences.

However, there are a number of preconditions, which may make the 'urban path' feasible for the Negev.

They are: (a) achieving the CM of urban population; (b) territorial contiguity of urban settlement; (c) provision of unique urban functions and attractiveness to investors; (d) infrastructure development; and (e) climate-responsive urban environment.

6.3. Achieving the CM of urban population

Upon reaching a certain population threshold, many urban places start to grow faster. Such a threshold may be termed the 'CM.' The main reason for the change in the pace of growth is simple. Residents of smaller localities are often denied access to social amenities that are concomitant with a larger settlement size. As the population of a community increases, it crosses the threshold for higher-level services, and offers more varied opportunities for employment, social services and leisure.

As Portnov and Erell (1998, 2001) demonstrate, the 'CM' for peripheral desert localities is not fixed. It depends on the physical remoteness of such localities from the major population centres of a country, so that more remote localities should be larger in order to become sufficiently attractive for both migrants and private investors.

In Israel, the 'CM' of small peripheral localities (measured in thousands of residents) was found to relate to the town's remoteness as follows: $CM = 3.2 \times IR$, where IR is index of remoteness, estimated as the road distance from the closest major population of the country in kilometres. According to this equation, a town, which is 100 km apart from one of the country's major population centres (Tel Aviv or Jerusalem), should have at least 320,000 residents ($3.2 \times 1000 \times 100$) to become sufficiently attractive to both investors and migrants (ibid.).

6.4. Territorial contiguity of urban settlement

Most often, peripheral desert towns are small and may not thus reach the 'CM,' which is essential for their sustained growth.[4] To achieve such a 'CM', desert towns may be grouped in clusters. 'Urban cluster' is a group of urban settlements located in close proximity from each other and connected by strong socio-economic and

[4] There are different definitions of sustained growth. Their analysis is far beyond the scope of the present paper. Following Turner (1993) and Portnov and Pearlmutter (1999, 332pp.), we adopt a simplified definition of sustained growth: a non-diminishing growth that endures over a prolonged period of time. In already densely populated 'core' areas, measures restricting further urban growth may be required. However, in sparsely populated, specifically peripheral, desert regions, future growth of urban settlement may become a desirable objective. Such growth may create a sufficient variety of employment and cultural opportunities, making desert towns more attractive and desirable for both their present-day residents and newcomers.

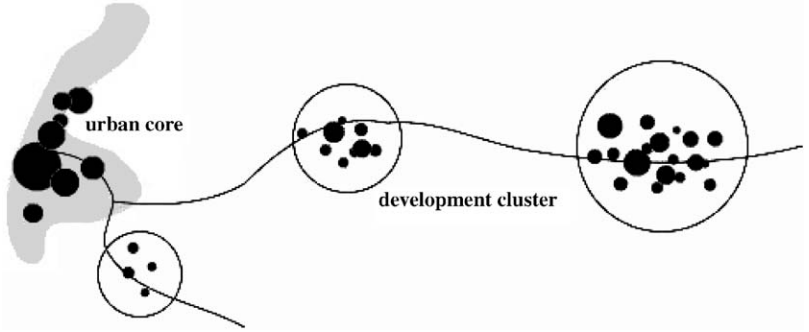

Fig. 6. Urban development in a desert region as clusters of towns.

functional links (Portnov and Erell, 2001). Very often, both investors and migrants consider urban clusters as integrated functional units, making their location decision hierarchically: first, among clusters, and then among individual urban settlements in the 'preferred' cluster.

The sizes of urban clusters are not fixed. They depend on the actual patterns of inter-urban commuting. If commuting conditions are better (in terms of roads, availability of public transportation, etc.), urban clusters extend over larger area. Like in the case of individual towns, the minimal threshold of cluster efficiency ('CM') is a function of the cluster's geographic location: Urban clusters established in more geographically remote areas should be larger in order to sustain the growth of individual towns (Fig. 6).

6.5. *Provision of unique urban functions and attractiveness to investors*

Neither physical location nor opportunities for functional exchanges *alone* may guarantee successful development of urban localities in peripheral desert areas. A clearly identified and well-established *motivating force* is required to drive such growth.

There are numerous functions and services that contribute to urban growth, but relatively few provide a sufficiently strong impetus to generate the wide range of regional multipliers essential for sustainable growth. Among such functions are universities and large hospitals, whose role in the formation of cities is profound (Felsenstein, 1997). Unless a small peripheral town possesses a considerable comparative advantage such as a coastal location or other unique natural resources, the establishment of the above educational and medical facilities may enhance considerably its development potential, at least initially.

6.6. *Infrastructure development*

Highway No. 6, also known as the 'Cross-Israel Highway,' is a major infrastructure project that is currently under construction (Derech Eretz Highways, 2003). The highway is the first toll road ever built in Israel which stretches over

320 km, from the Be'er Sheva area in the south to the region of Rosh Pina and Nahariya in the north (De La Roca, 1999; Griver, 2001). However, this highway only 'touches' the Negev, linking its northern part (the hinterland of Be'er Sheva) with other regions of the country. Therefore, the effect of this infrastructure project on the future long-term development of the Negev as a whole is likely to be limited. In contrast, the regional strategy we propose is based on a deep infrastructure penetration into the region, by creating a fast train line, linking most existing towns in the Negev–Sderot, Netivot, Ofaqim, Be'er Sheva, Tel Sheva, Arara BaNegev, Dimona, Yeroham, Mizpe Ramon and Eilat—both with each other and with the major population centres of the country (Fig. 7).

Such a train line will facilitate daily commuting between towns and cities in the region, making *existing jobs* more accessible to residents of small, specifically peripheral localities of the Negev. Furthermore, this train line may improve the existing image of most urban sites in the Negev as remote, isolated and hardly accessible. This will facilitate private investment in the Negev, resulting in more *new jobs* for its residents. As a result, the growth of Negev's urban sector may be better sustained. Importantly, railroad (specifically that driven by electric power) is more environmentally friendly than car roads, and will thus reduce environmental drawbacks associated with new development.

6.7. Climate-responsive urban environment

There are two essential advantages of peripheral desert cities to centrally located non-desert settlements. One of them is the relatively low land price, which may result in a relatively low cost of housing. This is a powerful advantage, specifically for a small country like Israel that is poor in land resources. This advantage may be especially important at the initial phase of urbanization. Though land prices in a desert region may increase as the region develops, they will always be lower than those in the country's overpopulated central areas.

Another potential advantage of a desert city is the higher availability of open spaces outside the city perimeter. As a rule, a desert city does not have developed agricultural hinterland, which often impedes a further expansion of non-desert cities. However, the importance of this advantage may diminish as a desert city grows. There are two main reasons:

- *First*, the urban environment is not functionally homogenous. In an established city, residential areas are surrounded by different land uses—industry, cemeteries, transport terminals, etc. If residential areas expand beyond this ring, they may become alternated by non-residential uses. This patchwork pattern disrupts functional links between residential neighbourhoods; it may also increase the level of air pollution in residential areas.
- *Second*, the territory of a desert city may not expand indefinitely. If it happens, the functional integrity of such a city rapidly diminishes. For instance, the city centre may become inaccessible to many of the city's dwellers. In the harsh desert climate, a long walk, waiting for a bus, may become prohibitive. Therefore, desert

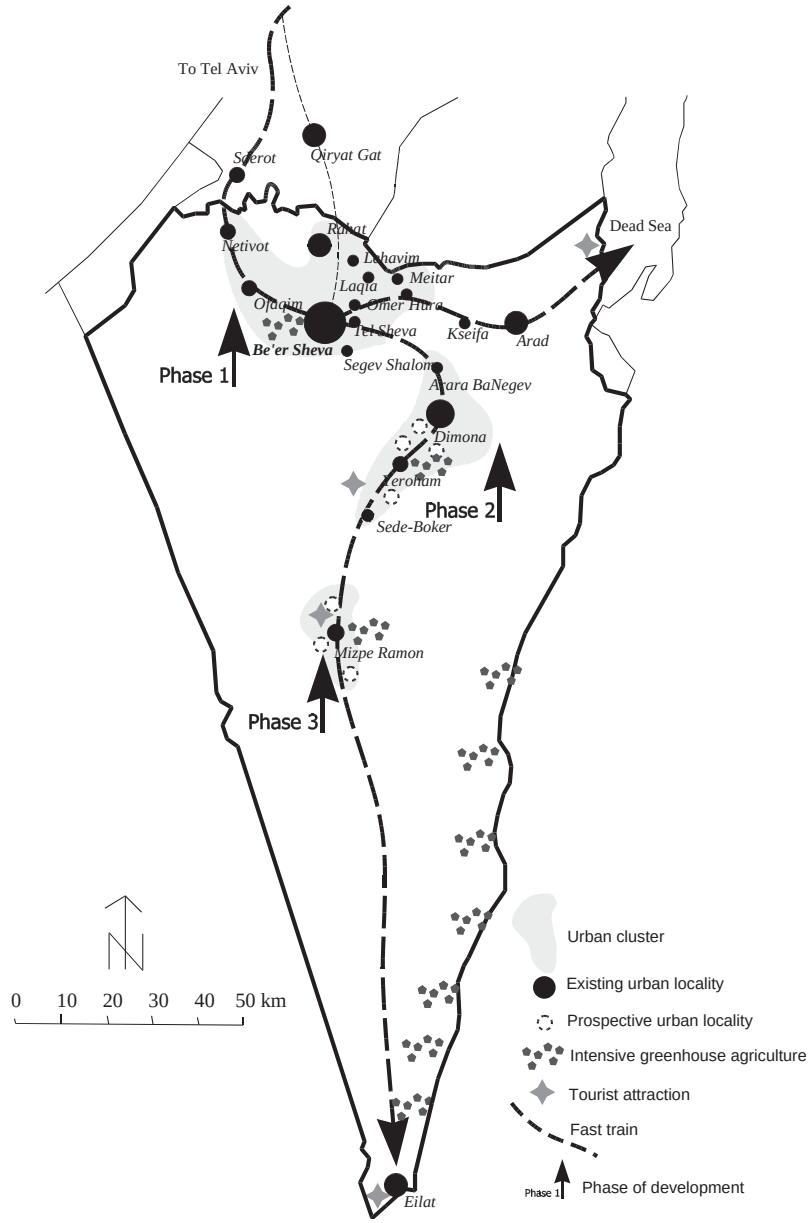

Fig. 7. The proposed strategy of development for the Negev region.

cities should be small and compact in order to function efficiently. If a need for expansion nevertheless exists, clusters of small, functionally integrated towns may become a viable option (Fig. 7).

Finally, we should mention a number of design features that may be especially beneficial for a desert city:

- *High density of development*: Narrow streets, small open spaces and high-density low-rise development of residential quarters provide effective shading and protection from blowing dust. Compact urban form also reduces the length of intra-city commuting, which is essential for residents of a desert city. As empirical studies (see inter alia Pressman, 1988; Portnov, 1992) show, people in extreme climates are more tolerable to high densities. If residents of climatically moderate cities prefer large open spaces, dwellers of climatically harsh regions often tend to smaller, more 'intimate' urban areas.
- *The use of water in open spaces*: In a dry desert climate, the use of small pools, fountains, sprinkles installed above pedestrian passageways may be very efficient. These devices may provide the efficient cooling of outdoor spaces. In contrast, the efficacy of such devices may be lesser in humid non-desert climates.
- *Enclosed courtyards*: Small courtyards attached to desert houses (if properly ventilated, sized and oriented) may provide cool air to indoor spaces and a place of retreat for residents, specifically during evening and morning hours. In contrast, in non-desert cities relatively large open spaces surrounding building may be more beneficial.
- *Building clusters*: In a desert city, building should be arranged in compact clusters with a clearly emphasized built perimeter. Such a perimeter protects internal spaces from cold winter winds and from sand storms during the summer. In contrast, in a non-desert city, building clusters may be more open towards the exterior, following the 'garden city' concept.

7. Conclusion

The pace of desertification in the Negev largely depends on development processes in the central, non-desert regions of Israel. As land resources for new development in these regions rapidly diminish, the development pressure on the Negev's resources may intensify. If the current trend of urban concentration in the central part of the country (which occurs mainly at the expense of agricultural land) continues into the future, agricultural activities will inevitably be forced towards the northern, semi-arid fringe of the Negev. This may result in the intensification of the desertification process in the region, due to agriculture-induced soil erosion and salinization.

The strategy for the Negev development we advocate is based on urban development, possibly accompanied by compact pockets of intensive greenhouse agriculture (Fig. 7).[5] Such a development may justify economically the often large investment required for the provision of drinking water and be least damaging for

[5] Although we are strongly convinced that the agricultural path *may not* become a viable option for the *large-scale development* in the Negev, small pockets of intensive greenhouse-based agriculture, such as those proven efficient in the Arava region, may be economically feasible. Moreover, they will also provide an additional source of employment for the local urban population.

the desert ecosystems, and compared to the agricultural path, may thus have less severe desertification consequences.

Another advantage of urban development in the Negev, as compared to the agricultural path, is reuse of treated wastewater. Such treatment (specifically that does not include desalinization) may be harmful if used for large-scale agricultural irrigation, but may work well in cities for gardening and mainly for cooling, especially if the cooling water is recycled.

For some of our readers, agriculture may be perceived as a productive activity, while urbanization may appear as a process that produces only cities and towns, but not livelihood. Such a perception is clearly mistaken. Urbanization is a 'growth machine' that generates both sources of livelihood and creates economic capabilities for bringing additional resources (such as fresh water) into arid regions; the wealth it generates may help to invest more in environmental protection and in the efficient use of resources. However, the process of desert urbanization requires special design and planning features that may make it viable. Such features (e.g. critical mass, territorial contiguity, provision of unique urban functions and climate-responsive urban environment) are proposed and discussed in this paper.

Acknowledgements

In its shorter version, the paper was presented at the Environmental Challenges in the Mediterranean (2000–2050) Conference, funded by the NATO-ARW Program and held on 2–5 October, 2002, in Madrid, Spain.

References

Abu-Rabia, A., 1994. The Negev Bedouin and Livestock Rearing. Berg Publishers, Oxford, UK, 139pp.

Barkai, Z., 1980. Urbanization processes in the central coastal plain and their effect on national economic planning and on the policy of population dispersal'. In: Harlap, A. (Ed.), Israel Builds 1977. Ministry of Construction and Housing, Jerusalem, pp. 8–13.

Ben-David, Y., 1993. The Urbanization of the Nomadic Bedouin Population of the Negev 1967–1992. Jerusalem Institute for Israeli Studies, Jerusalem (in Hebrew).

BIDR, 2000. The First National Report on the Implementation of the United Nation Convention to Combat Desertification. Jacob Blaustein Institute for Desert Research, Midreshet Ben-Gurion (http://www.unccd.int).

Bitan, A., Rubin, S., 1991. Climatic Atlas of Israel for Physical and Environmental Planning and Design. Ramot Publishing Co, Tel-Aviv.

De La Roca, J., 1999. The Trans-Israel Highway: Making Important Connections. Jerusalem Post, Jerusalem, 13 September 1999.

Derech Eretz Highways, 2003. Highway No. 6 (http://www.derech-eretz.com/Eng/aboutproject.asp; http://www.kvish6.co.il/).

Drabkin-Darin, H., 1957. Housing in Israel: Economic and Sociological Aspects. Gadish Books, Tel Aviv.

Etzion, Y., Portnov, B.A., Erell, E., Pearlmutter, D., Meir, I., 2001. An open GIS framework for recording and analysing post-occupancy changes in residential buildings—a climate-related case study. Building and Environment 36 (10), 1075–1090.

FAO/AGL, 2000. Terrastat—Human-induces Land Degradation due to Agricultural Activities (http://www.fao.org/waicent/faoinfo/agricult/agl/agll/terrastat/default.asp).

Felsenstein, D., 1997. Estimating some of the impacts on local and regional economic development associated with Ben Gurion University. Research Paper, Negev Centre for Regional Development, Ben Gurion University of the Negev, Beer Sheva.

Fialkoff, C., 1992. Israel's housing policy during a period of massive immigration. In: Golani, Y., Eldor, S., Garon, M. (Eds.), Planning and Housing in Israel in the Wake of Rapid Changes. Ministries of the Interior and of Construction and Housing, Jerusalem, pp. 169–177.

Golany, G., 1979. Israeli development policies and strategies in arid zone planning. In: Golany, G. (Ed.), Arid Zone Settlement Planning: The Israeli Experience. Pergamon Press, New York, pp. 3–42.

Gradus, Y., 1999. Planning in desert environment: three cases of responsive planning. In: Portnov, B.A., Hare, A.P. (Eds.), Desert Regions: Population, Migration, and Environment. Springer, Heidelberg, pp. 227–240.

Gradus, Y., Stern, E., 1980. Changing strategies of development: toward a regiopolis in the Negev desert. Journal of American Planning Association 46 (4), 410–423.

Griver, S., 2001. Trans-Israel Highway Divides the Country. Israel Magazine-On-Web (http://www.mfa.gov.il/mfa/go.asp?MFAH0j7w0).

ICBS, 1996–2001. Statistical Abstracts of Israel No. 47–52 (Annual). Hemed Press, Jerusalem.

ICBS, 1996–2001. Agricultural Survey. Israel Central Bureau of Statistics, Jerusalem.

Israel Ministry of Agriculture, 2003. Compensation for Water Allocation Cuts for 2002—Update (in Hebrew). http://www.moag.gov.il/.

Kipnis, B.A., 1989. Plant Scale and Manufacturing Policies for Peripheral Regions: An Intercultural Analysis of Israel, Brazil and Belgium. Avebury, Aldershot.

Knesset I., 2002. Report of the Parliamentary Inquiry Committee on the Water System in Israel, Jerusalem (in Hebrew).

Kressel, G.M., Ben-David, J., Abu Rabi'a, K., 1991. Changes in land usage by the Negev Bedouin since the mid-19th Century. Nomadic Peoples 28, 28–55.

Lipkis-Beck, G., 1997. Sitting on a Gold Mine. Jerusalem Post, Jerusalem, 22 January 1997.

Lipshitz, G., 1997. Immigrants from the former Soviet Union in the Israeli housing market: spatial aspects of supply and demand. Urban Studies 34 (3), 471–488.

MFA, 2001. Israel's Chronic Water Problem. Israel Ministry of Foreign Affairs, Jerusalem (http://www.israel-mfa.gov).

Middleton, N., Thomas, D., 1997. World Atlas of Desertification. Arnold, London.

NCRD, 1998. Statistical Yearbook of the Negev. Negev Centre for Regional Development and Negev Development Authority, Be'er Sheva.

Pervolotsky, A., 1995. Conservation, reclamation and grazing in the Northern Negev: contradictory or complimentary concepts. Network Paper 38a, ODI, London, 22pp.

Pervolotsky, A., Zeligmann, N., 1993. The myth of overgrazing in the Mediterranean scrub landscapes. Ecology and Environment 1, 9–17 (in Hebrew).

Porat, C., 1996. From Wasteland to Inhabited Land. Yad Izhak Ben-Zvi Press, Jerusalem (in Hebrew).

Portnov, B.A., 1992. Rational Use of Urban Land in Reconstruction Areas. Stroyizdat Press, Krasnoyarsk (in Russian).

Portnov, B.A., Erell, E., 1998. Long-term development peculiarities of peripheral desert settlements: the case of Israel. International Journal of Urban and Regional Research 22 (2), 216–232.

Portnov, B.A., Pearlmutter, D., 1999. Sustainable population growth of urban settlements. In: Portnov, B.A., Hare, A.P. (Eds.), Desert Regions: Population, Migration, and Environment. Springer Verlag, Heidelberg, pp. 37–60.

Portnov, B.A., Erell, E., 2001. Urban Clustering: The Benefits and Drawbacks of Location. Ashgate, Aldershot, 317pp.

Pressman, N., 1988. Developing climate-responsive winter cities. Energy and Building 11, 11–22.

Turner, R K., 1993. Sustainability: principles and practice. In: Turner, R.K. (Ed.), Sustainable Environmental Economics and Management: Principles and Practice. Wiley, Chichester, pp. 3–36.

WRI, 2001. Per Capita Water Consumption in Residential and Non-Residential Sectors. Water Research Institute, Technion, Haifa (http://wri.technion.ac.il/wc/page22.html).

Zeligman, N., Pervolotsky, A., 1994. Has intensive grazing by domestic livestock degraded Mediterranean Basin rangelands? In: Arianoutsou, M., Groves, R.H. (Eds.), Plant–Animal Interactions in the Mediterranean-Type Ecosystems. Kluwer, Dordrecht.