

The Role of Infrastructure in Facing the Challenges of Economic Development in the Mediterranean

Adapting Infrastructure to Climate Change Impacts: The Case of Tunisia

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Adaptation to climate change in southern and eastern Mediterranean countries is particularly relevant because of the expected strong effects on the region and the sensitivity of important sectors like agriculture and tourism to climate change. This work analyses qualitative scenarios with the support of insights from the theoretical literature and information collected from case studies about Tunisia. We deal with several dimensions of adaptation, including the role of the government, equity, uncertainty and linkages with mitigation. In general, we conclude that inaction is not a viable option, and this report shows how adaptation policy should be designed. We identify major areas of intervention, from removing barriers to private adaptation and the fostering of international cooperation.

This article explores the challenges to climate change adaptation in major urban infrastructure sectors with a focus on Tunisia, draws lessons from adaptation efforts under way in other large metropolitan regions, and discusses the role of the private sector in urban adaptation.

The importance of adapting infrastructure to climate change impacts is obvious – both in relation to the importance of infrastructure for all economic activities (and any nation’s economic success) and in relation to infrastructure’s role in protecting people and their assets from the direct and indirect impacts of climate change. The IPCC’s Fourth Report noted that “climate change can threaten lives, property, environmental quality and future prosperity by increasing the risk of storms, flooding, landslides, heatwaves and drought and by overloading water, drainage and energy supply systems” (Wilbanks, Romero et al, 2007);

the key role of infrastructure in reducing or removing these threats is obvious. Adaptation to climate change in southern and eastern Mediterranean countries is particularly relevant because of the expected major effects on the region and the sensitivity of important sectors like agriculture and tourism to climate change. Infrastructure networks will be affected by the physical impacts of climate variability and change, but will also play an essential role in building resilience to those impacts. Extreme events illustrate the extent of this potential exposure.

New infrastructure assets should be prioritized, planned, designed, built and operated to account for the climate changes that may occur over their lifetimes. Existing infrastructure may need to be retrofitted, or managed differently, due to climate change. Lastly, additional infrastructure, such as sea walls, will need to be constructed to address the physical impacts of climate change. This additional infrastructure can include traditional infrastructure, such as hard defences and other engineered solutions, as well as natural infrastructure.

The particular dimensions of infrastructure that are relevant to climate change primarily depend on location, exposure and vulnerability, as well as the degree of protection against climatic forces. This highlights some of the infrastructure most vulnerable to climate change in Tunisia as a means of illustrating the complexity of adapting in a dense, urban environment. Tunisia faces the following climate change hazards:

1. Temperature: long-term changes in mean annual temperature and increases in the frequency, intensity and duration of heatwaves;
2. Precipitation: long-term changes in mean annual precipitation and more frequent and intense precipitation events and drought; and
3. Sea level rise and associated storm surge

A number of similar adaptation strategies apply generally to different kinds of infrastructure and thus can produce benefits across multiple infrastructures at the same time. These adaptation strategies pertain to the redirection of water away from infrastructure, the choice of more resilient infrastructure materials to reduce the impacts and operational strategies. Some of these adaptation measures double as mitigation strategies as well, such as the use of insulation to reduce heat loads, which also helps to reduce energy use and thus greenhouse gas emissions. Key recommendations to create and implement effective adaptation plans are outlined below, many of which are already in place in Tunisia (Gaaloul, 2021).

Impacts of Climate Change and Water Resource Management in Southern Mediterranean Countries

The effects of climate change on the agriculture sector across a number of southern Mediterranean countries (Algeria, Egypt, Israel, Jordan, Lebanon, Morocco, Palestine and Tunisia) is cause for us to evaluate relevant policy measures that address these challenges for the region. The comprehensive assessments of climate change and its impacts in southern Mediterranean countries cover different sectors, ranging from physical climate drivers like temperature and precipitation, to agriculture, forests, water resources, social impact and policy evaluation. The evidence provided suggests the need for more effective adaptation measures for the agriculture sector across southern Mediterranean countries (Gaaloul, 2021). Climate change in southern Mediterranean Countries is predicted to affect farming destinations in terms of their competitiveness and sustainability, through a range of direct and indirect impacts:

- *Direct impacts* include the geographic and seasonal redistribution of climate resources for agriculture, and changes in operating costs (the resulting impacts on outcomes including prices, production and consumption)
- *Indirect impacts* due to climate-induced changes in irrigation water availability (precipitation changes, climate change-induced higher temperatures increase the water requirements of crops and livestock yields), services (water

shortages, water stress on irrigated crop yields) and the economic consequences of these potential yield changes

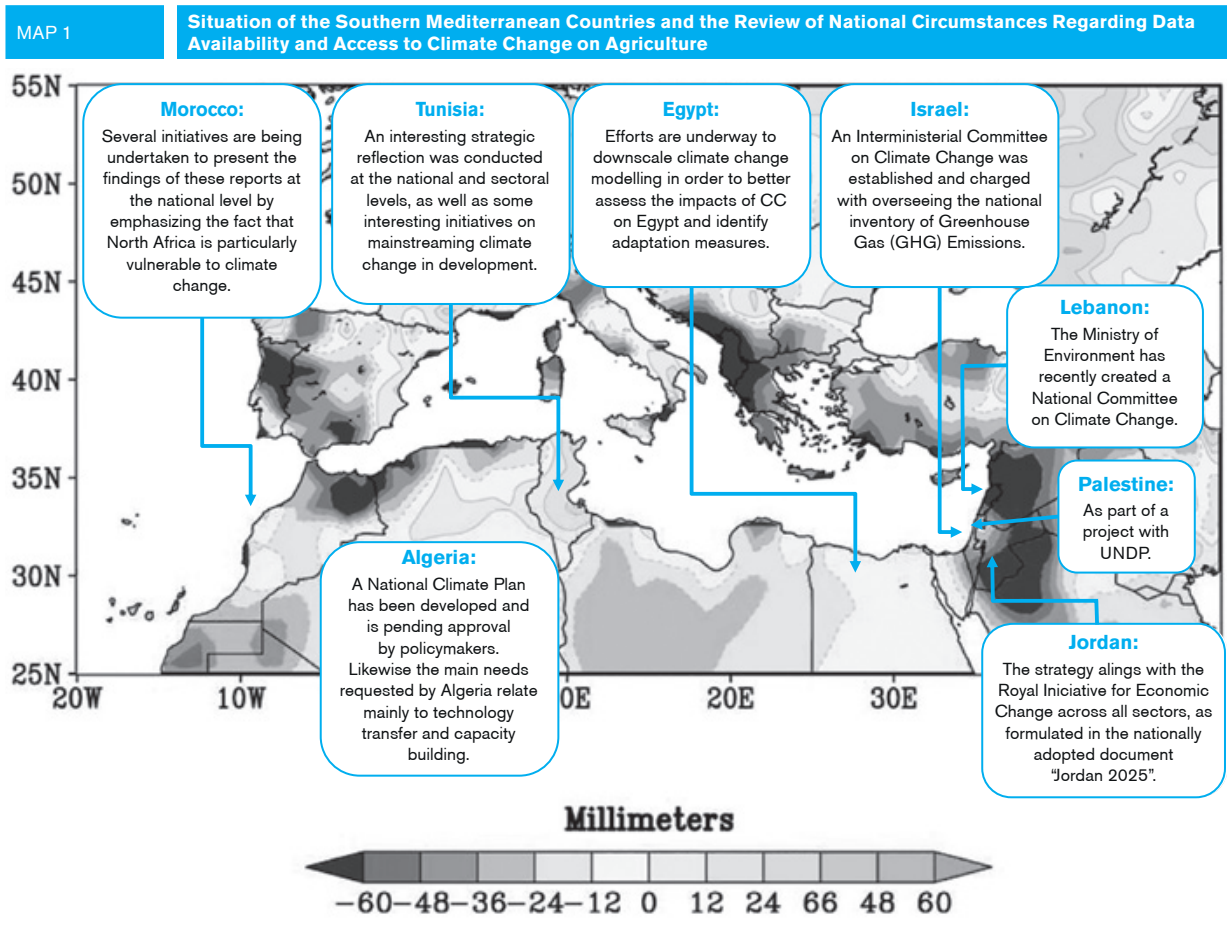
- *Broader impacts due to mitigation policies* on agricultural competitiveness such as increased fossil fuel prices and chemical fertilizers and mitigation measures for enteric fermentation

In the southern Mediterranean countries, surface water resources are limited, and groundwater is the main source of agricultural, industrial and domestic water supplies (Map 1).

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These impacts threaten the environment, society and economy, and can endanger human security. The assessment of relevant publicly available sources to build more resilient agricultural and water systems in the face of the challenges posed by climate change has confirmed that:

- *Adaptation of agricultural water management* requires combining the development of flexible and robust systems of water allocation to enable efficient reallocation of water in a context of strong uncertainty about future water supply and non-stationary climate with a time consistent, long-run incentive strategy for matching water demand and supply.
- *Negative socioeconomic impact of Climate Change for the agricultural sectors:* The climate change issue is global, long-term and involves complex interaction between demographic, climatic, environmental, economic, health, political, institutional, social and technological processes.
- *Climate change mitigation practices may have positive or negative implications on agricultural water management and water quality:* The potential synergies and trade-offs between mitiga-



tion and agricultural management practices are, however, site-specific and for many cases, there are substantial knowledge gaps.

- *Fostering an enabling policy and market environment for the adaptation of agricultural and water systems:* policy and market drivers form the overarching environment within which adaptation strategies take place. Policy failure can increase the cost of adaptation measures.

The adaptation investment is, in this case, a private good, as there is little room for the possibility of others to benefit from it. A reactive response is the other available option besides inaction (no response). Migration to another area after experiencing adverse climate impacts would make the individual better off, assuming improved weather conditions in the new location. Competition would even arise in applying for national or international funds for local infrastructure investment (e.g. groundwater recharge, irriga-

tion and flood protection). Such infrastructural intervention is clearly a proactive response to expected climate change, communities may also react less actively and choose internal schemes to mutually insure themselves from potential damage or simply leave individuals without any additional protection.

Climate Change Impacts on Infrastructure, Covering Coastal Infrastructure, Water Management and “Other Non-Emitting Infrastructure” (Roads, Bridges, Airports)

The infrastructure that is the focus for this paper obviously plays a leading role in adapting to most of the direct and indirect impacts of climate change – for instance to the increased risk of storms, flooding, landslides, heatwaves and drought and to the possibility of overloading water, drainage and the energy supply system.

According to a study on climate change impacts in Tunisia conducted in the framework of the National Adaptation Strategy, by 2030 and 2050, Tunisia will be facing two main, climate change impacts: a rise in temperatures and a drop in average rainfall levels. These climate changes are based on the already high degree of variability in the regional climate, which is even expected to increase by 5 to 10% on average between 2011 and 2070. In addition, Tunisia will experience a sea level rise from 38 to 55 cm by 2100. The whole country will experience a 1.1°C temperature rise by 2030 and a 2.1°C rise by 2050, in comparison with 1961-90. Summer temperatures (+0.9°C to +1.6°C) will rise more than winter temperatures (+0.7°C to +1.0°C). Extremely dry years will increase in frequency and intensity by 2030. Precipitation will decrease moderately by 5% in the north and 10% in the south by 2030 and by 10% in the northwest and 30% in the south by 2050 (MARH and Giz, 2007).

The potential impacts of climate change include the above-mentioned sea level rise, stronger and more frequent storms, temporary or permanent submersion of low coastal areas, accelerated erosion and increasing saltwater intrusions. These impacts will significantly affect the following resources and economic sectors:

Water resources. Accelerated sea level rise will damage the aquifer coastal formations and other underground fresh water resources due to the intrusion of seawater. The potential loss in coastal groundwater resources caused by saltwater intrusion is estimated at 53% of the current groundwater reserves. Water resources are of crucial importance in Tunisia, a country affected by aridity and a constant hydrous stress situation (less than 1,000 m³/capita/year). After 2025, it is projected that the situation in Tunisia will be the worse. In Tunisia, 51% of the water resources are surface waters and 49% are underground waters. Water exploitation ranges from dams (20.5%) and groundwater resources (33.2%) to deep water resources (46.3%). In terms of usage, 81% of all water resources are used for agriculture, 14% for individual use, 4% for industry and 1% for tourism. Water resources are particularly vulnerable to climate change (Gaaloul, 2021).

Natural ecosystems. Accelerated sea level rise will mostly harm humid places, such as lagoons, sabkhas and the lowest coastal marshes, due to sub-

mersion and salinization. The total amount of area potentially threatened by submersion is 18,000 ha. Not only does the State produce and distribute information, support basic research and take care of coastal protection and early warning systems, it also provides public goods in terms of the existing infrastructure, such as roads, railway systems and energy networks, which have to be adapted to endure climate change.

Coastal infrastructure. At present, 1.4% of the coastline is protected, mainly by dykes, which are particularly vulnerable to accelerated sea level rise. Thus, Tunisia's 22 coastal ports, 19 fishing ports, eight commercial ports and eight recreational ports are under threat. A study conducted by the Tunisian Ministry of the Environment (MEDD) and the UNDP (2009) attempted to assess the costs related to ASLR on the 2050 horizon. They distinguished the costs related to direct impacts from those costs arising from the degradation of the environment. Direct impacts include those on the infrastructure and on the main economic sectors on the coast (agriculture, tourism and the crafts industry). The losses in physical capital (mainly hotel infrastructure, water resources and housing zones) are calculated at more than 3.6 billion TD – which represents almost 10% of GDP – and mostly affect tourist regions, such as the Sousse Governorate and the region of Gabès/Médenine.

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Adaptation measures focus on urban planning and management activities, for instance, improving infra-

structure, adapting buildings and establishing new regulations, an early warning system for tsunamis and flash floods, limits to urban sprawl, controlling water consumption and expenditure on public health systems. The annual costs of impacts from natural hazards are estimated at 140 million TD (until 2030), i.e. 49-57 TD/person/year or 0.77% of the present GDP. The total annual costs of adaptation measures (2020-50) are calculated at 612 million TD and benefits at 870 million TD, thus slightly exceeding the damages caused by climate change. Johnson and Breil (2012) suggest public funding with an estimated need for investment of 654 million TD over the entire time horizon: 339 million TD in the short term (< 5 years), 2 million TD in the very short term (< 2 years), 337 million TD within five years and 315 million TD in the medium term (< 10-15 years). They conclude that Tunisia has not implemented any adaptation measures yet, but that the agglomeration has the capacity to do so.

The impact of climate change on tourism goes in both directions: tourism is very vulnerable to climate change but it can also contribute to or exacerbate it

The construction of long-lasting infrastructure, such as roads, bridges, railways or complete plants, is particularly suited to the real options investment approach. Instead of the careless construction of a road in a low-lying area with an uncertain flood risk and a possible later resettlement of the route, it is very likely less cost-intensive to purchase additional land areas that can be used for future flood protection. Once again, the maintenance of flexibility can be quantified by the option value to demonstrate the benefit of purchasing additional land.

Agriculture (citrus fruit, irrigated crops, etc.) is particularly vulnerable to salinization and soil erosion. The loss of agricultural land is estimated at about 16,000 ha. In addition, accelerated sea level rise can damage agricultural infrastructure, such as drainage and irrigation pipes. The impact on fishing is positive, with a slight production increase of 1

million TD per year. Undoubtedly, the country has to deal with limitations in the coordination of parties involved in decision-making mechanisms, difficulties in arbitrating various water needs (including environmental), while ensuring attention is given to drinking water and agriculture, degraded infrastructure and the management of irrigation and drainage systems, the implementation and monitoring of existing laws and regulatory frameworks for groundwater conservation, particularly in terms of imposing penalties, and the insufficient financial resources for the necessary interventions in infrastructure, water management, training and awareness-raising.

Tourism. Accelerated sea level rise will affect the aesthetics and size of beaches in the three main tourist hubs, Hammamet, the Sahel and Jerba. Currently, more than 40% of Tunisia's beaches are considered vulnerable or highly vulnerable to accelerated sea level rise. The impact of climate change on tourism goes in both directions: tourism is very vulnerable to climate change but it can also contribute to or exacerbate it.

Climate change will affect infrastructure provision and operation, with the severity of these effects depending on the overall emissions pathway and decisions resulting in increased exposure of assets and mal-adaptation. Projections from the IPCC find that the following impacts are likely to occur by the year 2100 under the low emissions (RCP2.6) and high emissions (RCP8.5) pathways (IPCC, 2014). Overall, there is more confidence in temperature projections than those for precipitation or sea level rise (Shepherd, 2014). Modelling of future socioeconomic scenarios suggests future emissions are unlikely to reach the levels implied by RCP8.5 (Riahi, et al., 2017).

Flexible, adaptive approaches to infrastructure can be used to reduce the costs of building climate resilience given the uncertainty about the future. Climate model projections are a significant source of uncertainty, particularly on a regional or local scale, but other factors (such as socioeconomic changes) are also relevant for climate resilience. Decisions about infrastructure should consider relevant uncertainties to ensure resilience across a range of potential future scenarios.

Climate impacts are projected to lead to increases in investment required for infrastructure, particularly

water storage, flood defences and water supply and sanitation in Tunisia. The use of tools for decision-making in the face of uncertainty can reduce the need for costly retrofitting while reducing upfront costs.

Experience in Tunisia suggests that it is relatively easy and uncostly to adapt most forms of infrastructure for most locations to the likely impacts of climate change up to 2030 – although increasingly less so with longer term horizons, especially where mitigation is unsuccessful

Nature-based, flexible or innovative approaches to climate-resilient infrastructure may even be cheaper than traditional approaches.

Climate-resilient infrastructure has the potential to improve the reliability of service provision, increase asset life and protect asset returns. Building climate resilience can involve a package of management measures (such as changing maintenance schedules and including adaptive management to account for uncertainty in the future) and structural measures (e.g. raising the height of bridges to account for sea level rise or using natural infrastructure such as protecting or enhancing natural drainage systems).

Decision-makers need to have access to high quality information, consistent data and have the capacity to use this information to inform planning. Uncertainties should be clearly communicated and valued, and there should be access to the tools needed to support decision-making in the face of uncertainty. The use of platforms and online tools can provide accessible, credible and transparent information on past and future climate behaviour. Access to information should be complemented with the development of the technical and institutional capacity to manage climate-related risks.

The expected increase in the frequency and scale of climate phenomena (such as floods, heatwaves, dust storms and sandstorms, etc.) will severely tax the Tunisian infrastructure. Also, the expected rise in sea levels will cause serious problems for a great

many facilities and infrastructures located in coastal areas, especially since the “climate change” factor was not taken into account when almost all of Tunisia’s infrastructure was designed. In Tunisia, the impact of infrastructure damage may affect the economy to such an extent that it gives rise to social and even political unrest.

The following actions are especially necessary to help the Tunisian region to adapt its infrastructure to the impacts of climate change.

Enhance Tunisia’s ability to assess the vulnerability of their infrastructure. Projects should be urgently developed and implemented to train executives in the relevant national institutions and organizations in techniques for assessing infrastructure’s vulnerability to the impacts of climate change, and also to provide said institutions and organizations with the necessary technical, human and financial means to make vulnerability assessments.

Integrate the “climate change” factor when planning and designing facilities and other infrastructure elements. In this context, support from developed countries is particularly necessary both financially and as regards technical assistance and the transfer of technologies.

Promote technology transfer to combat coastal erosion. Coastal erosion is an issue of concern almost everywhere in Tunisia and it generates significant ecological damage through natural habitat losses. It also generates damage to infrastructure, agriculture lands and settlement areas. The sea level rise will increase this phenomenon and its impacts at ecological, economic and social levels.

In this field, cooperation and technology-transfer projects are needed to help the region’s countries master the required technologies for monitoring and modelling coastal erosion. Priority should be given to areas with high human settlement density, islands and natural habitats that are particularly sensitive, such as mangroves and coastal areas.

Conclusions

Experience in Tunisia suggests that it is relatively easy and uncostly to adapt most forms of infrastructure for most locations to the likely impacts of climate change up to 2030 – although increasingly less so with longer term horizons, especially where

mitigation is unsuccessful. There are also high-risk locations and/or with particularly high-adaptation costs. But the basis for estimating the costs of infrastructure adaptation is not present in developing countries for at least two reasons: (1) There are very large deficits in infrastructure provision in Tunisia – which means that the issue is not only infrastructure adaptation, but also provision for infrastructure that does not currently exist to standards that make sufficient allowance for the direct and indirect impacts of climate change. (2) There is very little detailed location-specific assessment of what it would cost to ensure there is climate-resilient infrastructure in place (which includes adapting existing infrastructure and filling infrastructure deficits). Conventional methods for estimating adaptation costs for infrastructure are generally based on the cost of modifying existing climate-sensitive infrastructure – but this cannot produce valid estimates if there are very large deficiencies in infrastructure provision. In addition, since so much adaptation requires local investments rooted in very particular local contexts by local authorities, households and community organizations, estimates for the investments needed for adaptation are impossible without detailed local cost assessments – yet none of these were found in Tunisia. There needs to be promotion of the transfer of technologies for analysis, risk assessment and infrastructure adaptation, which are needed for managing water resources. This will enable Tunisia to successfully adapt their infrastructure for managing water resources to climate change, to benefit from a transfer of the appropriate technologies for risk analysis and to develop tools to help decision-making.

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