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Reversing Salt-Induced Land Degradation Requires Integrated Measures

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Agricultural crops take up water, but not salt, and evaporation from irrigated land does likewise. The result is increasing salt levels in soils. Just as cities cannot ignore urban wastewater collection and treatment, irrigating farmers and irrigation districts cannot ignore what to do with the salt in agricultural drainage water. Although salt management techniques can seem straightforward, the long-term sustainability of irrigation in arid and semi-arid areas, where most irrigation takes place remains a challenge. Salt-induced land degradation is on the rise in several major river basins. Salt-affected lands remain valuable resources that cannot be easily abandoned, given their importance for food security and regional economies, as well as the significant investments in infrastructure that have been made on these lands. This policy note discusses the status of salt-induced land degradation and addresses two key questions: Why has progress been so limited in addressing salt-induced land degradation? And what measures could be taken to prevent and reverse such degradation?

1. Limited Progress to Date in Reversing Salt-Induced Land Degradation

Measures to prevent, minimize, or overcome salinization of land and water resources have been known for some time (Oster *et al.* 2012). Yet, agricultural land degradation from salt build-up continues to occur. Globally, the extent of salt-affected irrigated lands in the last two decades has increased by more than a third, from about 45 million hectares (ha) in 1990 (Ghassemi *et al.* 1995) to 62 million ha — an area the size of France, representing 20% of the world's irrigated land — in 2013 (Qadir *et al.* 2014). Simple extrapolation suggests that every day another 2,000 ha of irrigated cropland is impaired by salinity.

Lacking comprehensive basin-wide efforts, salinity and drainage problems persist in many key production regions that rely on irrigated agriculture. Well-known examples include the Aral Sea Basin (Amu-Darya and Syr-Darya River Basins) in Central Asia, the Indo-Gangetic Basin in India, the Indus Basin in Pakistan, the Yellow River Basin in China, the Euphrates Basin in Syria and Iraq, the Karkheh River Basin in Iran, the Murray–Darling Basin in Australia, and the San Joaquin Valley in the United States. The environmental changes resulting from salinization of land and water in the Aral Sea Basin and shrinkage of the Aral Sea are considered to be the largest caused by humanity in Central Asia in recent times (Cai *et al.* 2003; Qadir *et al.* 2014).

Most governments in major river basins in arid and semi-arid areas have historically focused on the expansion of irrigated area without paying much attention to salt management (Wichelns and Oster 2006). Irrigation scheme planners focused on water quantity and ignored the fact that water quality inevitably degrades along the sequence of subsequent water uses. They did not account sufficiently for the downstream effects of excessive irrigation, and assumed that the surface runoff or deep percolation from one farm would be beneficial to other farms in the downstream areas (Wichelns and Qadir 2015). Consequently, irrigating farmers were not encouraged to use water efficiently to minimize the addition of salts to surface streams and groundwater. In fact, the practice '*irrigate now, manage salts later*' has tended to persist until salt build-up reaches alarming levels.

2. High Time to Reverse Salt-Induced Land Degradation

Food security concerns, amidst scarcity of freshwater and new productive land in arid and semi-arid areas, have put productivity enhancement of saline water and salt-affected lands on the policy agenda. This has been accompanied by a call for sustainable agricultural intensification — amidst the emerging understanding that the increase in crop yields has fallen substantially below the growth observed from the 1960s through the 1990s (Ray *et al.* 2012). Salt-induced land degradation in key irrigated regions is a major cause of this decline.

This makes it high time to consider strategic options for sustainably increasing irrigated agricultural output, particularly in areas prone to salinization. Policy makers may be tempted to ignore the problem and focus on intensifying the application of inputs, but that will lead to further degradation. Alternatively, moving away from salt-affected land will neglect potentially valuable production resources. Instead, there is a need to think and act in the range between ignoring and giving up. This means recognizing widespread salt-induced land degradation as key threat to sustainability of irrigated agriculture, and devising strategies to prevent, minimize or overcome salinization of land and water resources.

Research and practice have demonstrated that recycling and reusing saline water until it becomes unusable, while returning salt-affected irrigated areas to higher levels of production, enable significant contributions to food, feed, fiber and renewable energy production without expanding crop acreage (Qadir *et al.* 2014). Pertinent actions and strategic investments in salt-affected irrigated zones can reduce poverty, generate economic benefits, and ensure equitable social development for smallholders and marginalized groups. Other benefits include mitigating climate change impacts through enhanced soil carbon sequestration.

3. Six Elements of a Sustainability Strategy

Here are the six key elements of a broad strategy for reversing salt-induced land degradation in irrigated areas.

3.1. *Revisit national political agendas and policies*

In developing countries with major irrigation schemes, the political agenda and associated policies tend to favor expanding irrigated area over providing effective drainage systems to existing irrigated lands. Most farmers try to maximize current net revenues, while delaying the necessary investments in salinity and drainage management. Such policies and practices result in short-term benefits, followed by salt build-up and productivity declines. As this happens, most developing-country governments look for cosmetic solutions. This leads to scattered salinity management efforts, with insufficient financial resources and limited, often outdated, strategic planning for salt and drainage management.

National-level integrated strategies, facilitated by supportive policies, are the key to salt management. This will require drainage systems and mechanisms leading to the concentration, transportation, and safe disposal of excess salts. Such strategies could be incorporated in action plans at the country- or basin-scale, drawing on a broad range of disciplines to ensure effective removal of barriers to adoption. The Murray–Darling Basin Salinity and Drainage Strategy Framework is a good example. Since this framework is based on the biophysical and economic conditions in Australia, it should not be superimposed elsewhere without consulting local stakeholders and analyzing the biophysical aspects of affected areas; the socio-economic situation of the associated communities; the availability and cost of equipment and soil amendments; the availability of skilled professionals; and relevant institutional arrangements and supportive policies.

Given the prominent role of irrigation and drainage in salinity management, such action plans should also consider water politics and policies regarding water quality and quantity in transboundary rivers; land-use options and strategies (including commitments to long-term renting of land to large companies or neighboring countries); national bioenergy production strategies; markets for salt-tolerant plant species; potential economic gains from sustainable land management in the affected areas; and national climate change management strategies.

3.2. *Strengthen institutions and promote collaboration*

Supportive institutions and institutional collaborations needed to implement integrated salinity management strategies are generally either absent or ineffective. Even when institutions do exist at the national, provincial, or local levels, they do not have sufficient human and financial resources or infrastructure to address salinity management, particularly in developing countries. For example, the drainage infrastructure installed during the Soviet era in the Aral Sea Basin does not function well due to weak institutions and lack of funding. This vast infrastructure network includes over 80 storage reservoirs; 47,000 km of partly lined main and secondary irrigation canals; 270,000 km of tertiary irrigation canals; 145,000 km of collector drains; 8,000 vertical drainage wells; and hundreds of large pumping stations and water control structures.

Farmers acting alone do not have sufficient incentives, capacity, or funds to implement salinity and drainage management strategies on their own (Wichelns and Qadir 2015). Therefore, the implementation of national- and basin-level salt and drainage management strategies requires the strengthening of related institutions and enhanced institutional collaboration, particularly in countries where farmers rely on public investments in irrigation and drainage, such as the Aral Sea Basin.

3.3. *Improve understanding of the economics of action versus no action*

Current information on the economic implications of salt-induced land degradation is mostly confined to impacts on crop yields — including losses from salinity or gains from specific beneficial management interventions. But these analyses generally ignore a whole range of additional costs from salinization, including damage to the environment and ecosystem services; deterioration of roads, railways, buildings and other infrastructure; declines in farm property values and farm- and district-level employment (including possible out-migration); and finally the attendant social costs of declines in farm businesses and loss of cultural heritage. In addition, most economic analyses are restricted to the farm scale, with limited data to draw implications for implementation at the watershed or basin scales.

Policy makers need to have this broader perspective to evaluate and decide on public investments in regional salt and drainage management. It is therefore essential to undertake comprehensive evaluations with reference to the economic cost of no action (benefit loss due to salt-induced land degradation under "business-as-usual") and the net economic benefit of action (derived from preventing and/or reversing land degradation). Undertaken at the basin or watershed scale, such evaluation should include both market and non-market impacts and benefits.

3.4. *Develop human resources*

There is a critical shortage of skilled human resources to address the complexity of irrigation, drainage, and salt management sustainably. Although many scientists work in this area, they generally have little or no training in recent approaches for managing salt in irrigated areas. Outdated concepts remain in practice despite the availability of modern tools, such as transient-state models that enable the application of precision salt leaching to control salinity. Salt leaching requirements based on steady-state conditions, established several decades ago, are still widely used to assess the suitability of water for irrigation and salinity control. Most analysts still rely on time-consuming salinity assessment methods that require collection of soil samples from different soil depths and laboratory analysis using conventional instruments and procedures.

The professionals dealing with irrigation and drainage management need to learn about transient-state models that enhance understanding of salinity impacts on crop yields and provide sharper insight regarding pertinent irrigation, drainage, and salt management strategies (Oster *et al.* 2012). Knowledge of remote sensing, geographic information systems, and satellite imagery also can expand capacity to monitor and assess irrigated, salt-affected, and waterlogged areas and develop real-time options to prevent and reverse salt-induced land degradation at the watershed and basin scales (Wichelns and Qadir 2015).

Another priority is expanding the cadre of social scientists with background in salinity, which is needed to analyze the social and cultural dimensions of salt-induced land degradation and its mitigation.

3.5. *Encourage the private sector's involvement and expand market access*

In addition to farm production and revenue losses, salt-induced land degradation may negatively affect business and industrial sectors either directly or indirectly, targeting their inputs, outputs, or processes. Examples include reduced productivity and availability of raw material and utilities used in industry; limited options for diversification of inputs and processes; impacts on workforce availability and business operations; lost profits with declines in product quality and brand reputation; and constraints on further investments and expansion (Qadir *et al.* 2014).

Among the sectors potentially at greatest risk are those closely connected with natural resources. These sectors may deal with basic resources (forestry, wood, pulp, and paper), food and beverage, construction and materials, industrial goods and services (transportation and packaging), utilities (water and electricity), personal and household goods (clothing, footwear, and furniture), leisure and travel (hotels and restaurants), and real estate (ELD Initiative 2013). Reversing salt-induced land degradation would help these sectors reap economic gains by providing needed levels of materials and goods and services, while having positive effects on employment and other economic sectors.

A range of plant species can be grown on salt-affected lands. Yet some salt-tolerant forages, grasses, shrubs, and medicinal and aromatic species may have missing or limited markets in regions where they might otherwise do well. This implies the need to establish new markets for the introduced plant species on local, district and regional scales, linking output to potential demand centers. Existing markets for such plans can also be strengthened by the introduction of quality testing and certification.

To encourage private sector involvement in this way, it will be necessary to involve a range of relevant stakeholders including farmers, business and marketing sectors (local businesses, industrial suppliers, brand owners, and marketing agencies), and public institutions (research and extension institutions, land survey and classification units, irrigation and drainage departments, and government offices). Supportive government policies can catalyze private sector action.

3.6. *Engage farmers and communities*

In the absence of effective regulatory measures for irrigation, drainage, and salt management, farmers in arid and semi-arid areas will continue to apply excessive irrigation water for short-term benefits, despite harmful longer term impacts on the productivity of their lands. They also have little incentive to optimize their irrigation deliveries and manage deep percolation to minimize impacts on other farmers and downstream water users.

In at-risk areas, farmers need to shift away from conventional irrigation practices in specific ways, such as: growing crops that can tolerate the ambient salinity levels in soil and irrigation water; improving water management based on minimum leaching fractions, in some cases through the use of advanced irrigation methods; and maintaining soils in good physical condition, including adequate permeability to meet crop water and leaching requirements (Oster *et al.* 2012).

Widespread adoption of minimum leaching fractions will lower the cost of regional drainage systems for removing saline drainage water and maintaining sufficient depth to shallow water tables. Providing economic incentives to irrigators and generating funds for infrastructure development will help prevent and reverse degradation of land and water resources at the watershed and basin scales.

4. Attaining Success Will Require a Paradigm Shift

Since land is not a fast-moving good or service, the time horizon for reversing the degradation trend and restoring degraded lands may be years, and perhaps even decades. But it is essential to jump-start this process now. Strategies are needed to showcase the importance and awareness of reversing salt-induced land degradation, along with the rewards of investing in sustainable land management. A variety of policy actions are needed to incentivize widespread adoption. The technologies for irrigation, drainage, and salt management are readily available, but they won't be sufficiently adopted without a paradigm shift from '*irrigate now, manage salts later*' to '*irrigation vis-à-vis salt management*' to harness maximum benefits from their use in specific situations. By promoting this shift, public leaders and policy makers can enhance the pace of achieving sustainable irrigation, drainage and salt management, and significantly contribute to food and water security.

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