

Review

Rethinking Rehabilitation of Salt-Affected Land: New Perspectives from Australian Experience

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Abstract: Soil salinity is a major threat to the sustainability of agricultural production systems and has defeated civilisations whenever the cost of remediation exceeded the benefits. Among the reasons for this is the complexity of the plant-water-soil nexus and that the causes of salinity are often separated from the damage in time and space. There have been many activities to address salinity, and while good progress has occurred in commercially attractive irrigation areas, many apparently successful techniques, such as intercropping obligate halophytes with conventional crops, processing halophyte meals for human consumption and new uses for saline waters, have not been taken up, although the benefit in ecological terms is understood. There are limited payments available for some ecosystem services, but these are not yet a very recognised market for land users, whose agency is essential for long term success and addressing this requires institutional evolution. We conclude, from Australian experience, that a more concerted effort, perhaps initiated by a philanthropist, is needed to show merchants and agencies how a range of payments for ecosystem services can be turned into true markets in an aggregate way so the ‘knowledge of what can be done can be transformed into benefit’.

Keywords: salinity; natural resource management; ecosystem services; markets; exchanges; transformational change; halophyte agriculture



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1. Introduction

Coevolution of plants and animals, including humans, has produced a situation where 7.8 billion people are now sustained by agricultural production based on soils and water favourable to high net primary production (NPP). Population growth impelled this coevolution [1,2]. By 2050, Earth’s population is predicted to reach 9.9B [3], which will require a doubling of the current food production to ensure food security. Global climate change and rapid expansion of the world’s economy also adds to pressures on the environmental systems that sustain the production of goods and services [4], with economic penalties exceeding 170B p.a. [3].

Over the last 50 years, per capita availability of arable land has decreased by about two-fold, due to increasing rates of urbanisation and land degradation caused by various environmental constraints [5], pushing agriculture into marginal lands. In most cases, such lands could be made productive only by irrigation. Worldwide, current freshwater withdrawal for irrigation purposes ranges between 25 and 80% of total freshwater resources [5], and is only going to increase, given the growing frequency and severity of drought events [6,7]. However, reliance on irrigation for agricultural production comes with an additional and a very substantial issue of land salinisation [8], with between three and six tons of salt (primarily NaCl) added to each hectare of farmland every year with irrigation water [5]. Thus, we have no choice but to make better use of the landscapes we

have already exploited and accept the fact that agriculture in the 21st century will inevitably become saline.

Among the complexity of salinity is the issue of scale. While the degradation is local many of the associated benefits, including biodiversity gain and climate mitigation accrue at aggregate scales or in locations remote from where the problem originated. Although salinity is but one form of damage to the natural resource base being carried by water, its damage is insidious and incurred also by associated infrastructure. This is often not considered in programs to address salinity at its source even though the damage to ancillary installations and equipment in many situations may exceed that to agriculture per se. One authoritative analysis for the Murray Darling Basin of Australia concluded that salinity damage to agriculture was only about 32% of the total damage to the Australian economy, the rest being damage to urban structures, logistical infrastructure, and water reticulation systems [9].

Saline water per se, particularly saline effluents that also pollute other water bodies, also constitutes a very significant related problem [10]. Dealing with these waters incurs cost, but also represents some opportunities when treated in an integrated way. The quantities are significant [11] and, given the predicted decline in availability of freshwater resources [12], may represent a substantial economic opportunity.

In this article, we take a wider look at land and waterscapes, seeing them as systems that link damage and repair across time and space to bridge the divide between the main beneficiaries of ecosystem services and the main actors, the land users. We first discuss the land-soil-water nexus of crop reduction by salinity and the evolution of ideas about how to shape these better. We then discuss the livelihood needs of land users to shape these better and the limitations of the single issue and reward approach common hitherto. We discuss the different ecosystem benefits and payments that have been useful, but insufficient in isolation, often due to existing policy constraints with those in Australia as an example. Lastly, a technical and economic tool that links more of the possible income sources and services required for the remediation of land and water in several land use categories based on experience in Australia is adapted and presented.

2. Salinity, Area of, Distribution in Australia and Severity of

The National Land and Water Resources Audit's dryland salinity assessment, in collaboration with the states and territories, defined the distribution and impact of dryland salinity across Australia. Best available estimates in 2000 showed that about 5.7 million hectares of land were within regions identified as being at risk of or affected by dryland salinity.

2.1. Primary and Secondary Salinity

Primary salinity occurs naturally and is the result of rainfall interacting with geographical features over thousands of years. Secondary salinity is the result of human land use and either produces more salt or causes primary salinity to rise to the surface of the land. Western Australia is most affected by salinity in Australia, with around 70% of arable land suffering from land salinisation. Over 2 million hectares are currently affected, and around 4 million hectares of land are currently listed as high risk, and 50% of divertible water is already considered overly saline.

Salt becomes a management issue when it threatens assets such as water resources, biodiversity, agriculture, and infrastructure. Water can mobilise salt stored in the ground and transport it vertically and horizontally. Effective management of salinity requires an understanding of its causes, location, and behaviour in the landscape [13].

Dryland salinity is seen as one of Australia's most serious environmental and resource management problems. There have been major government programmes in place for over a decade aiming to increase farmers' adoption of management practices for salinity prevention. Farmers have responded, although, not on the scale recommended by hydrologists, and salinity is continuing to worsen. Why is this so?

2.2. *The Farmer's Perspective*

2.2.1. Farmer Responses to Salinity

Encouraged by policies such as the National Landcare Program, many farmers have been making personal sacrifices and financial commitments to salinity prevention under the impression that the treatments have been officially sanctioned and will be sufficient. Although the sacrifices of time, labour, and finance loom large to these farmers, we now know that the treatments implemented are too small by an order of magnitude or more to significantly reduce eventual areas of shallow water tables, although, local effects providing worthwhile delays are likely. In salinity-prone regions there are only localised areas where the water table has been brought under control.

Over 50 percent of farmers in study in WA reported that they had not observed any benefit at all from their land conservation investment, so the prospects for much larger investments would appear very poor.

Lack of awareness of salinity is probably not a major factor explaining slow and low adoption of the recommended practices. Rather, the major factors relate to the economic costs and benefits of current treatment options, the difficulties of trialling the options, long time scales, externalities, and social issues. This combination of factors means that the problem in many regions is extremely adverse to rapid adoption, probably more so than for any other agricultural issue in Australia. In other words, farmer reluctance to adopt the radical changes being recommended is completely understandable and, indeed, reasonable from the farmers' perspectives [14]. Curtis et al. [15] emphasised lack of financial capacity as the greatest impediment to change. Others have highlighted the profitability of an innovation as being a particularly important factor influencing its attractiveness to farmers. Economic modelling indicates that on-farm benefits from salinity prevention are likely to contribute little to the economic attractiveness to farmers of switching to perennial-based farming systems based on long lived crops, agro-forestry, or even halophytic shrubs. Thus, the consideration of salinity prevention does not change the earlier broad conclusion that the on-farm economics of current perennial options are adverse in most locations. Therefore, faced with clear evidence that land users cannot be expected to underwrite the repair of a nation's environmental woes, the search for more just and equitable financial incentives must be found and mechanisms such as payment to land users for the ecosystem goods and services flowing from their particular piece of land deserves more consideration.

A further consideration is that saline soils and associated saline water are considered differently institutionally and by different stakeholders. Saline water is likely to be a bigger threat to infrastructure of interest to local government or roads and railway operators than to land users. However, such resources, that might be available to land users, treated as a resource may have significant value. For example, to substitute for valuable potable water, or to earn income from new unconventional uses, land-based aquaculture, power generation etc. as also reviewed below. Salinity is a broader system than is commonly supposed by most institutions that have addressed salinity historically.

2.2.2. Institutional Constraints and Opportunities

The complex institutional situation faced by farmers in Australia is a constraint, but some opportunities have emerged from attempts to overcome this. Constitutional responsibility for land and water is a state responsibility through different departments while most taxing power and so ability to invest public money resides with the Federal Government. Local Government is largely funded locally but the rate base tends to be small towns concerned with infrastructure and services rather than rural land, now in the hands of fewer land users. Although salinity is a real risk to this infrastructure, they lack sufficient funds to address these comprehensively.

There are opportunities to direct investment towards activities to promote ecological resilience and the electorate has demonstrated a willingness to fund this in a significant way. As reviewed below, institutional innovations have occurred to assist land users to access this, but these have in the main been dominated by Governments with short term

time horizons and the commercial sector interested in dealing with ecosystem services, such as carbon credits, have not found a way to relate to the broader range services required for success and to other payments for eco systems so it has been hard for land users to see a real market in the range of activities necessary to address salinity and related saline water.

There is an opportunity for interested stakeholders to enable land users to access more of the payments available for ecosystem payments with an evolution of the institutional systems reviewed below. Success in reducing salinity impacts would in turn increase both farmer's productivity and net primary productivity (NPP) and so establish a new virtuous cycle where the reverse exists now.

3. Soil Salinity and Plant Productivity

The absolute majority of staple crops are classified as glycophytes and show a very significant growth reduction when grown in the presence of salt in the root zone [16]. This is specifically true for wheat, rice, and maize—three cereal crops that are responsible for over 50% of calory intake by humans. For example, a 50% reduction in yield has been measured for rice at 80 mM NaCl, while for durum wheat this threshold is ~100 mM [16]. Salt tolerance was present in wild crop relatives but then lost during domestication process [17–19], alongside with tolerance to other abiotic stresses. This is hardly surprising, as human selection targeted mostly agronomical traits such as reduced seed shattering, absence of the secondary dormancy, and fewer and more upright tillers (in cereals) or fruit size, shape, and an ease of harvesting and/or transportation (in horticultural crops) [20,21]. Moreover, a human-driven selection of crop species for the Na⁺ exclusion trait (the mainstream trend in breeding over the last several decades) has come with a high carbon (ATP) cost for osmotic adjustment [22], thus imposing significant penalties on production.

While the need to improve salinity stress tolerance in staple crops is now recognised as one of the key priorities [23], the progress in a field is much slower than required, due to highly complex physiological and genetic nature of this trait. In this context, there is no single gene that can be targeted by molecular editing to improve salinity tolerance, and assembling a dozen of complementary mechanisms in one ideotype via marker-assisted selection is also not practical. The most promising approach would be to re-domesticate current crops for the lost halophytism [5]. However, this requires a major shift in the breeding paradigms and takes time. So, what can we do in the short-term to handle this issue?

4. Halophytes as Cash Species

A small group of terrestrial plants can not only tolerate substantial amounts of NaCl in soil solution but also benefit from its presence [24–26]. These plants are termed halophytes and represent a valuable resource for both using salt-affected lands and utilizing low-quality saline water (Figure 1) [27].

Halophytes have long been advocated for use as forage, fodder, oil seeds, and pharmaceuticals [27–30]. The use of halophytes as salad vegetables have commanded a high price [31], although, the choice of species is quite limited. This is hardly surprising as according to eHaloph, a registry of all halophyte species [32]: out of some 351,000 species adapted to fresh water, only 1386 are listed as salt tolerant, and only 525 can tolerate 70% of seawater. Thus, only about 0.15% of all flowering plants may be classified as true halophytes. As a result of this, the use of halophytes in conventional agriculture is extremely limited, with the notable exception of quinoa. Quinoa (*Chenopodium quinoa*) is an annual pseudo-cereal crop originating from the Andes that possesses exceptional nutritional qualities and a superior salinity stress tolerance [19,33,34]. Compared to conventional grains, quinoa seeds lack gluten, have a superior ratio of proteins, lipids, and carbohydrates, a higher content of essential amino acids, and are rich in minerals and vitamins [19], and its cultivation is expanding globally [35]. However, a broad application of quinoa as an alternative pseudo-cereal crop in Australia is limited by the fact that most quinoa cultivars have short-day requirements [19], and this species also does not possess sufficient heat

tolerance (being originated from high-altitude regions in South America). Thus, the future of quinoa as a crop in Australia requires its further domestication for the above traits [3,19]. Selections of *Distichlis palmeri* have also been investigated encouragingly but inconclusively for this purpose, as it is a true halophyte, is also gluten free, and has a high content of essential amino acids [36–39].

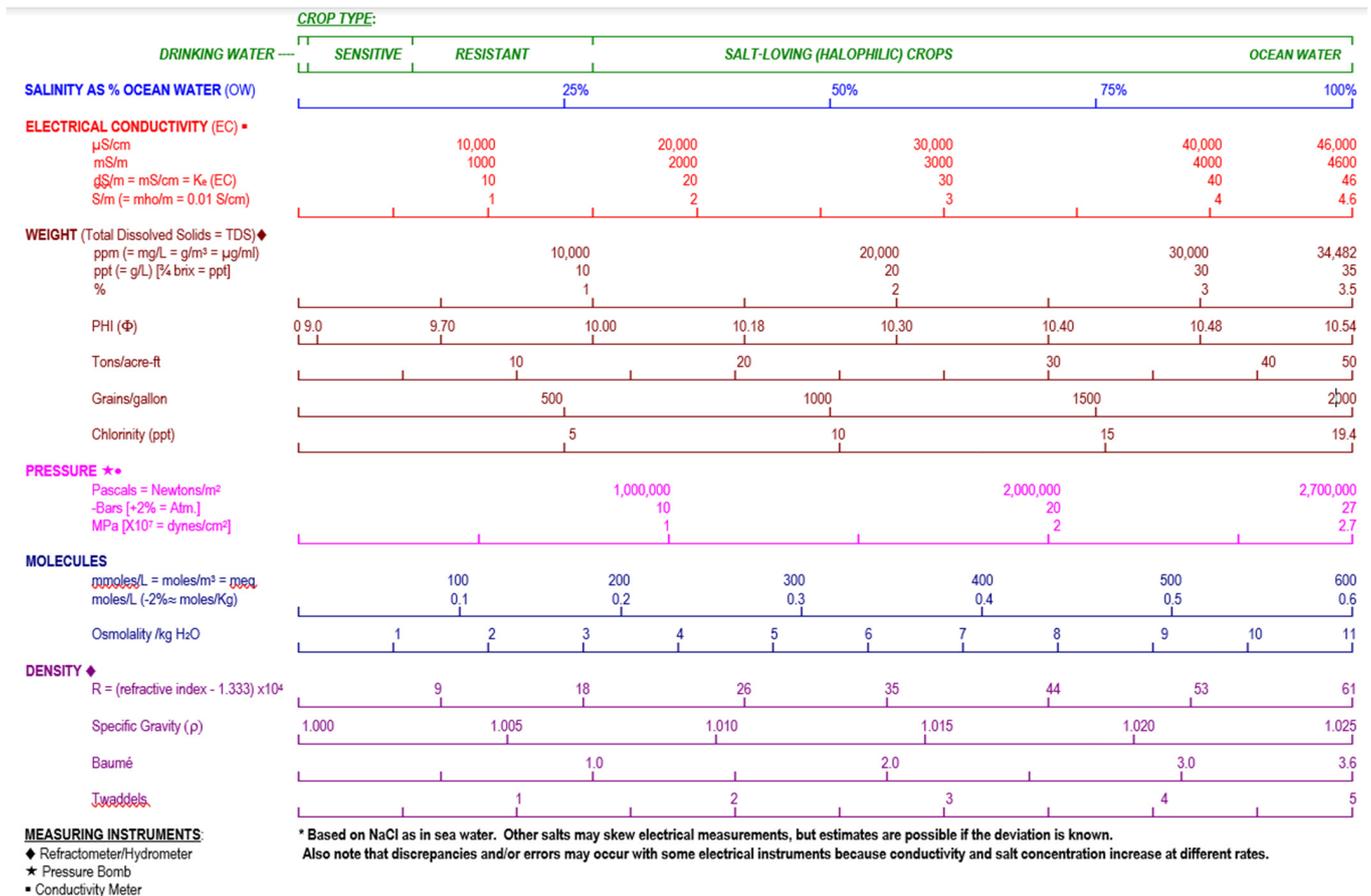


Figure 1. The Yensen scale depicting plant-soil relationships. Meq: = milli equivalents/litre; PHI: power of hydro impurities log (g salt/g water) + 12. From Nicholas P. Yensen, with permission.

Halophytes may also represent a highly valuable resource for desalination and phytoremediation of degraded lands [27,40]. The studies of soil-plant relationships are amongst the oldest in science, beginning at least with Aristotle. The technology of irrigation arose even earlier along with practices to leach the damaging salts. However, long term irrigation in dryer regions usually led to substantial salt build up in the soil, impacting its structure and chemical properties, and eventually its sustainability as an agricultural system. Efforts to delay or ameliorate these effects through leaching these salts differs between soils and the science of irrigation hydraulics and soil treatments continues to evolve with new materials, irrigation technologies and markets. Pasture improvement programs in salt-affected regions throughout the world have used halophytes and salt tolerant shrubs and grass species [28,41]. Trees and shrubs can be valuable complements to grasslands because, being perennial deep-rooted species, they can significantly reduce saline shallow groundwater tables.

5. Towards a Systems Approach to Halophyte Agriculture

The parsimonious course for land managers is to address only the needs of their location and to consider their situation as a new system rather than a particular problem such as the wrong plant or soil treatment [42]. This may result in learning to live with

and to take advantage of salinity where it cannot be removed or sequestered away from 'productive' plants and land.

Halophytes utilise a broad range of physiological and anatomical mechanisms assisting their adaptation to saline environments [43]. This includes using Na^+ and Cl^- as 'cheap osmotica' to maintain cell turgor [22,25,44], as well as operate their stomata [45], pronounced tissue succulence that allows more efficient vacuolar salt sequestration [46,47], the presence of highly specialised structures such as salt glands or epidermal bladder cells, [48–50], more efficient redox homeostasis, and more efficient chloroplast operation [8,51,52]. These adaptations are individual genetic traits, usually not dependent on each other as assemblages and no halophytes possess all of them. Some of them may be required for conditions of extreme salinities, while others may be more essential for less severe environments. The selection of halophyte plant species is thus context and system specific, of which the degree of salt tolerance may not be as significant as some other factor, such as tolerance of waterlogging [53,54], or a high value product type. In many circumstances a combination of halophytes may be the best low risk approach to ameliorating the salinised situation. Many saline areas are a mosaic of still productive and degrading regions, usually for topographic reasons so the selection of plants may include trees, conventional glycophytes and a range of halophytes such that they reinforce each other bio-physically across a landscape [55,56]. A very promising technique here is companion cropping, or intercropping, where the obligate halophyte thrives in saline conditions, uses some of the saline water, and can remove some soil salt through its salt glands [43] and benefits the growth and production of the associate usual crop, for example tomatoes, [57].

Soil conditions can vary significantly over short distances and assessing and planning for these can be costly [58]. In many circumstances a cost-effective means to map these is required for efficient establishment and to monitor differences over time if the associated ecosystem services are to be marketed [59,60].

Very often the cost, time, and this complexity defeats individual farmers or land managers, although, they may prefer to address the problem if they perceive a solution to be possible, even if the return is lower. This may be for aesthetic reasons, or to avoid the problem spreading to other areas if not addressed [61]. The answer pursued under many officially supported programs to address land degradation is to fund projects justified by the ecosystem or public good values of the investment, but these interventions may not persist unless the actions are seen by the farmer or land manager to be profitable and largely conform with their experience and values, a view well reviewed by Squires [62,63].

6. Economic Rationale and Decision Making

Most investigators researching ways to deal with salinity provide some economic justification for their suggestions. This is true for both agricultural, livestock, and aquaculture production [39,64–66], as well as remediation of mined, contaminated, or desert soils [67], including reducing saline water tables [68–70]. A similar analysis has been conducted for the use of halophytes in carbon sequestration [67,71–74], and for the overall role in landscape management [40,63,75–77]. However, the net effect is to miss the effect of multiple benefits (except for the landscape view), and importantly, not to view their idea from the perspective of the farmer or land manager whose agency is essential if the suggestions are to be taken up in the real world [60].

The above reviewed literature does not sufficiently deal with the difference between the overall economic benefit of regenerating degraded salt land and the financial benefits to the investing land manager whose agency is essential if change on the ground is to occur. Ignoring the immediate needs of rural populations is one commonality that has led to the failure of many similar Natural Resource Management (NRM) projects in the past, in the face of widespread interest in ecosystem services [78]. Ecological restoration of salinised land has been successful in many different locations around the world, even in severely degraded regions where lives and livelihoods were in jeopardy but if it has not really suited the land user/manager it has not been sustained [60,63,79].

Salinity is but one, relatively intractable, form of land or landscape degradation but its impacts, for example biodiversity loss and soil structural change, are common to others such as erosion and acidity. Astute choice of halophyte(s) can be used to reverse these impacts by improving biodiversity, biomass production above and below ground, soil structure, water holding and cation exchange capacity, and to sequester carbon. Yet, only the above ground gain in biomass can be easily monetised by the land manager and this is often insufficient incentive. Some farmers also invest to address salinity for aesthetic reasons; land conservation ethics are important where there is community support to address social decline in degrading landscapes but are not necessarily applicable in all landscapes and not sufficient in themselves [14]. Public or other external investment support is necessary to generate the ecosystem, public good, aspects of rehabilitating saline land and water, considered externalities.

As implied, these are benefits (or costs) that occur incidentally to the main purpose of an investment. They can be encouraged (or discouraged) by deliberate policies or payments to influence land managers. Australia has investigated and successfully used salinity credits as a specific return for investments addressing salinity, usually to reduce salinity in irrigation water and irrigation runoff. These have been mostly successful at the interstate level to account to each other and the electorate for state government investments, and in connection with meeting 'end of valley targets', which relate to regional investments [80]. They have been much less used for individual credits, because of the difficulty of monitoring changes in salinity at this scale [81]. For land managers to access such income opportunities some collaborative arrangements are necessary.

7. An Essential Role of the Land User

Farmers and other land users are most interested in restoration of their own land. In this context the goal is not about returning damaged land to some notional pristine state, it is about restoring ecosystems to an acceptable level of functionality, a problem common to many disturbed lands such as mined land as discussed by Tongway et al. [82].

The difficult task for the land manager is to decide what is possible and profitable, particularly considering the scale and technical complexity. The difficult task for the external financier is to make a cost effective and accountable connection with land managers who can deliver the desired ecosystem services.

Much institutional attention in planning is directed towards stakeholder consultation, 'learning from the farmer', and in supporting direct investment to demonstrate successful technology and approaches to restoring saline lands. However, Australian, US, and other international experience has been that official support is costly and the activity ceases once the official support ends [83]. This problem can only be solved by the additional activity, be it payment for ecosystem services or some novel use of degraded water or land, becoming a real market seen of value to the land manager. This in turn will require a transformational change in how natural resources are managed and this requires a much more sustained approach, as articulated in Young [84] and Leake [79].

Putting these two world views together, that of the farmer or land manager on one hand and the investor in ecosystem services on the other, is the desired outcome of this transformation and for this to occur some mechanism, such as that depicted in Figure 2, is required to cross this divide, to 'bridge the gap' [60].

This illustrates an approach to addressing complexity in a collaborative way, between afflicted farmers in a district or watershed, between afflicted people in a region connected hydrologically to land managers seen to be causing the damage, although separated in time and space, and between external agents interested in supporting activities to address salinity.

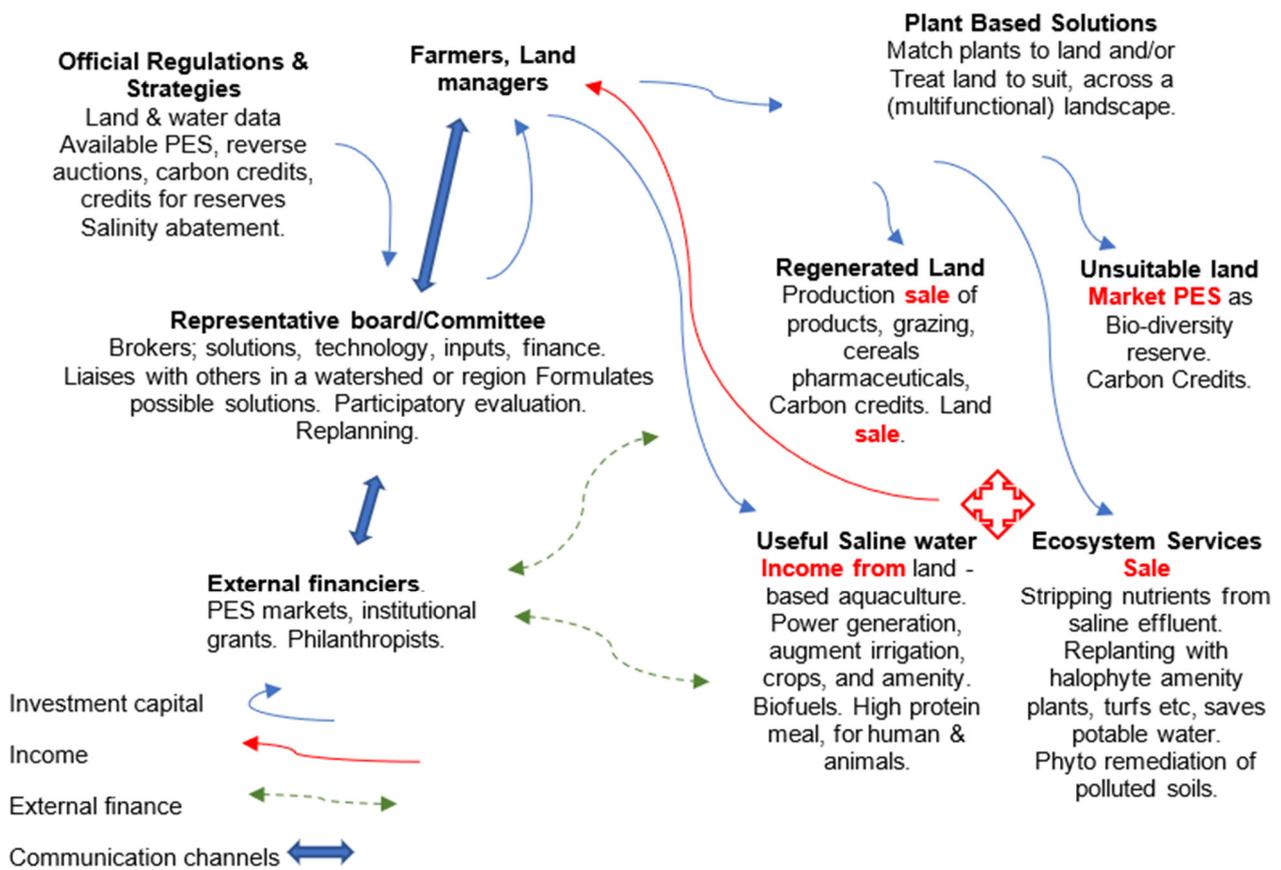


Figure 2. An approach to utilizing land and water degraded by salinity.

A key element of this system is the focus on finding and supporting an adequate source of income for the farmer and other land manager’s investment in these activities, as their agency is essential if the knowledge about what can be done is to be transformed into benefits. This approach shifts the context of land use planning and management towards the land manager while retaining something of the benefits of scale, technology, markets, and availability of finance inherent in official schemes. It gains in appreciation of local variations that occur in many landscapes, particularly saline ones, and in the sense of ownership that results from participatory approaches. It rests on experience with NRM in Australia and elsewhere [85,86], and in small holder extension [87] and might operate as an ‘exchange’ at a regional level, much as with commodity futures.

The left-hand side of Figure 2 depicts non-land manager inputs of (i) official policies and incentives intended to facilitate or enable land manager action, (ii) external finance or markets directed towards ecosystem services, and (iii) a land manager and farmer representative board or committee to enable collaborative action, in the long run to be funded as a secretarial and brokerage service. The right-hand side divides the possible actions into activities to match the farmer’s particular soil, water, and market circumstances to specific plant-based solutions, which may vary across their landscape and include some continuing fresh-water plants. This may yield income from some traditional and some new products from the regenerated land. This will enable ‘rezoning’ of unsuitable land as reserve land, for example, bio-diversity purposes with income coming from sale, carbon gains, or official incentive. Some land may be suited or suitably located to earn direct income from ecosystem services, for example the use of halophytes able to strip nutrients from saline effluents prior to discharge to reduce eutrophication or contamination with pathogens, effectively the ‘scrubbing’ action of a wetland able to tolerate salt. This service by a knowledgeable salt land farmer may take place on other land depending on the quantity and location of intended discharge.

Saline water, also shown in this figure, deserves to be treated separately to degraded land for the many situations where the quantity is very significant, and it can be addressed as a water rather than a land investment. Although this may involve the use of degraded land, the income to be derived from increasing the value of degraded water would form the main activity.

8. Valuing Water

Degraded water comes in many forms and can be considered to have a negative value, providing a clear income objective, increasing its value from negative to whatever other use it may be applied [88]. Many of these forms of degradation are also accompanied by salinity, which is a significant and under-appreciated factor in treatment or in utilizing the resource. In the case of a plant-based solution, for example to strip nutrients from an effluent stream, salinity seriously reduces the range of plants that can be used [89]. Globally, some 80% of wastewater is discharged into rivers [10].

Addressing degraded water problems may occur in one of three directions or as a combination: (i) activities to reduce or eliminate the damage in return for payment for the service; (ii) activities to substitute for or 'stretch' fresh water by mixing the waters; and (iii) activities towards some production that makes use of the water, and/or the nutrients it contains and is rewarded in the normal way through the sale of products.

Examples of (i) include payments by a food processor or irrigator to compensate the receiver of the water for taking up the nutrients before disposal of clean saline water to an aquifer or other water body [40,65,89]; payments by an infrastructure owner for diverting saline water from the foundations, or water reticulation, or irrigation system, or irrigated land [79]; payments for phyto-remediation of waters through the removal of metal salts (including radioactive), sodium, and others via serial bioconcentration; and payments for phytoremediation of saline oil field wastes [90]. Examples of (ii) include the direct use of degraded water in an income earning activity, such as land-based aquaculture and other saltwater-based food production systems [91]; or amenity areas replanted with salt tolerant species [92,93], with the income generated from a share of the saved high-value potable water; and in irrigation of common crops through water blending [66]. Finally, activities towards production that makes use of the water may include the use of nutrient-rich saline water in the production of forage or animal feed meals and oil seeds [27], to grow energy crops, biofuels, and pharmaceutical plants [27,94], sometimes as companion crops [57], and generate electricity from the salinity and or temperature gradients in saline ponds [95].

Each of these uses can be considered novel, justifying an establishment investment, even where they are practiced regularly now, such as stripping nutrients from effluents, as the presence of salt(s) has potential impacts on the local environment, notably soils, aquifers, and other receiving water bodies, and associated infrastructure, buildings, roads, and reticulation systems. Assessing and guarding against such risks is a prerequisite to investment and requires specialist input. In Figure 2. above, the land manager through the representative board, would have the responsibility of liaising with regulatory authorities on these aspects and contracting specialist services, in addition to its other duties of brokering markets, finance, and specialist technologies.

Striking a value for water is very much location and context specific; at one extreme the value of water is infinite since life is impossible without it, at the other extreme, for example in floods or heavily pathogenic polluted situations, it is quite negative. In many cultural settings it has a spiritual value that is difficult to even articulate, let alone ascribe a monetary value to. Water is often only given a value related to its cost of handling and storage but in some circumstances the value of infrastructure to be protected means this can be quite high. These issues are discussed in a recent UNESCO Valuing Water Report [96].

The representative board or committee has the task of addressing this issue of negotiating locally relevant value in collaboration with relevant officials, and then in brokering sales and finance with interested parties (Figure 2). For this, they require a typology of mapping tools able to economically describe the ecological situation at the appropriate

scale to support the mobilisation of payments for environmental services (PES) in a useful way [97]. Such tools are vital in capturing the linkages between investments in salinity with relevant infrastructure, to mobilise the different types of finance available for linked investments. This is increasingly possible in an era of heightened awareness of climate impacts on water, which emphasizes the integrated nature of most investments in NRM issues and the linked co-benefits [88].

9. Investment Sources

Investment in salinity mitigation has normally come through official channels and are directed towards research or ground mitigation, augmented by farmer input with the benefits being seen only in salinity terms, usually expressed in increased production. The linkages between the co-benefits of this investment with other aspects of natural resources management have seldom, until recently, been visible to the land manager or financiers. More and more of these linkages are becoming evident so that investments directed towards a particular outcome, for example biodiversity conservation, climate mitigation or water quality is seen to generate others as co-benefits. In this new environment, it behoves investors in NRM, as farmers or land managers, to quantify and articulate these linkages. In this way, more funding can be directed towards integrated activities, which will have a significant impact on the amount a land manager can apply to each situation and so possibly reach a threshold for investment.

Investment sources that might be applied in these ways include (i) usual official investments, but aggregated where possible to achieve co-benefits, (ii) institutions interested in each specific benefit, and (iii) international and Ethical Investment Funds, mediated by a regional or local collaborative body.

Official Australian investment in NRM, including for salinity, from all levels of Government, has a regional delivery focus suited to regional mediation, to try and achieve co-benefits [86,98]. However, this has not yet sufficiently involved the private sector to become a real market, although merchant interest in climate mitigation is increasing rapidly in Australia, and internationally [99]. The major international sources include International Finance Institutions (IFIs) including the World Bank, the Asian Development Bank, and the International Fund for International Agricultural Development (IFAD), often through dedicated funds such as the Green Development Fund, the Global Environmental Fund (GEF) and the bilateral development agencies of OECD countries.

The challenge for supporters of the idea of creating a real market for more of the benefits that accrue from successful rehabilitation of salt-affected soils and water is to find a way to fund the process long enough to demonstrate how they can be captured, to merchants, PES traders, and development institutions. For the initial step, an interested philanthropist, or farsighted merchant, might be needed.

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Resources Management Council in 1994 and the Mid-term Review of the National Dryland Salinity Program Phase II in 2000 for Land and Water Australia, (Australia was spending \$135 m pa on this program at that time), and many other related consultancies and practical activities in Australia and internationally since. This review synthesises this experience. Sergey Shabala acknowledges support from the Department of Industry, Science, Energy and Resources (project AISRF48490), China National Distinguished Expert Project (WQ20174400441), grant 31961143001 for Joint Research Projects between Pakistan Science Foundation and National Natural Science Foundation, and Chinese National Natural Science Foundation (Project 31870249).

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