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Irrigation for Sustainable Agricultural Development in Ethiopia

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Background

Soil is the dust of life. It is the basic foundation of agriculture, the prime industry in Ethiopia, and the spear point for sustained development. Therefore, there is a conjugal bond between people and soils. Not in the near future will we shift to food production in ponds to be securely comfortable. Hence, since we cannot live without soil, we could live better if we knew more about the the soils endowment in the country given the ample opportunities that exist to address the issue. Otherwise, in the absence of reliable information, generalizations that border on myth can develop on soils where diversity of sharp contrast is the rule than the exception in Ethiopia.

The marked heterogeneity is reflected by soils that range from immature to old in terms of soil development. The immature Inceptisols, Entisols have poor nutrient and water holding capacity. The young Aridisols in the semi-arid areas are rich in basic elements but pose problems related to salts. Here parent material is the dominant factor and the role of the biosphere is small. There are also the shrink-swell clay soils, Vertisols, in the highlands, the arid and semiarid regions. They have severe physical constraints including poor traffic ability and poor drainage during the rainy season. Alfisosls, the most predominant soil in Ethiopia are widespread in the highlands, arid and semiarid regions. They have poor soil structure, are highly prone to accelerated erosion, and easily crusted and compacted. On the other hand the organic matter rich and fertile Mollisols are developed under grassland vegetation. Under high rainfall are the old Oxisols and Ultisols are poor in many essential elements but rich in iron and aluminium that could be toxic. Both are highly susceptible to erosion and nutritional constraints (Mesfin, 1998). Therefore, among the three types of environment that higher plants encounter – bodies of water, air, and soil – the soil as an open system is by far the most heterogeneous and complex.

Despite the diverse nature of mosaic soils, in the past, coaxing enough food has been guided by the logic: plow more land and food supply will flourish accordingly. Yet, exploitative practices have left scar on the loom of soil on which the web of life is woven. Climate change has also threatened even areas that were once considered to have reliable rainfall. At the face of such a calamity, farmers and pastoralists had to walk between the raindrops to make ends meet!

Changing the situation with the modification of traditional land use has required the introduction of irrigation. It compensates the deficiency of rainfall such that crops would not be deprived of water. Hence, irrigation is no more a choice but a necessity for accelerated but sustained development. Accordingly, policies, and strategies are being implemented with the participation of the people and other relevant stakeholders.

With the wind of change in the country farmers are drawn into to the market economy given the attractive opportunities. They have shown the disposition to free themselves from traditional restraints and demonstrated their capacity to rapid change. Thus, small-holder agriculture is no more simple 'farming' but has become a business where the dynamic situation has demanded innovative adjustment. More change has also come with the investment of the private sector in the new frontier of large-scale agriculture. But, it has to take into account the diverse soils in different agro-ecological zones. Given the rapidly changing dynamics of agriculture and rural development, soils as the vein of life have to be handled in accordance with their potentials and limitations.Then, drawing upon the general outline of soils in Ethiopia but with particular reference to the special features of the vast salt-affected soils, multiple avenues can be exploited to enhance their unique agricultural potential with the infusion of knowledge-based technology. Based on lessons learnt from unfavorable practices, it is possible to ensure sustainable development and avoid the irirreversible degradation with due care to a habitable environment.

That is why there is the need to generate and disseminate information on the world of soils with particular reference to irrigated agriculture.The development of technological packages with links strengthened between the agricultural and non-agricultural sector can help answer the "what" "where" "how" and "when" of investment-smart agriculture on soils in tune with ruling cycle of nature. As a result, not only new lands but substantial area that otherwise would be abandoned and others now considered marginal can be put into sustainable productive agriculture.It is with this view that the threats posed and the ample opportunities offered by the transformative irrigated agriculture are treated to ensure ample latitude for accelerated but sustained agricultural development in Ethiopia.

Formation:

Large areas are arid and semiarid because they are by-passed by the hydrologic cycle. Hence, high concentration of soluble salts and exchangeable sodium are the facts of plant life over large area. The two are products of base-rich primary minerals and weathering rocks. When exposed to the action of water and carbonic acid large quantity and variety of salts dissolve. The sources of salts also include saline parent materials, fossil salt deposits, irrigation waters and fertilizers with high salt index.Since leaching is weak in the semi-arid areas, these accumulate in soils. Again, drainage water contains more salt than irrigation water applied. If irrigation water comes in contact with fossil salt, it causes their dissolution and accumulation (Levy et al. 1984 and USSLS 1954). Secondary salt accumulation occurs from mismanagement of

Effect

The soil-plant system is a continuum but an ideal condition is hardly met in salt-affected soils. Mineral stresses that impinge on cropsoccur due to soluble salts, sodium, and specific ion toxicity on the one hand and the deficiency of nitrogen, phosphorus and a host of micronutrients on the others. Unlike some plants that are collectively called halophytes (salt plants) because they accumulate and tolerate high salt concentration, most domesticated crops do not possess special adaptationt thrive in saline habitat. Hence, soluble saltsproduce harmful effects on crops by reducing the availability and uptake of water (salinity effect). This means plants must have the competence to absorb sufficient amount of water to avoid 'desiccation' or physiological drought. Hence, plants have to fight fire with fire to maintain still higher concentration of salts. Thus, they expend energy which could have been used for healthy growth and high yield. They must also adapt to whatever adverse conditions that prevail in soils. Among others, deficiencies of macro- and micronutrients occur from interaction with sodium, calcium and magnesium. In addition, chlorine, boron and other ions when present at high concentrations are toxic (USSLS 1954)).This means that crops with different parts of their structures in entirely two different media - the roots in the soil and the shoots in the atmosphere- have to adapt to these conditions to be productive.

There is also the condition of sodium-rich soils. Sodicity (alkalinity) is of permanent nature than salinity because it persists even after soluble salts are removed (sodicity effect). Exchangeable sodium alters soil physical properties with the swelling and dispersion of soil. Such poor structure results in restriction of water movement,seed germination and root penetration, the soil becomes massive and puddles easily even when little water is applied. Thus, it aggravates the problem of land preparation because the soil becomes difficult to till. There are also nutritional disorders caused due to decreased availability of essential nutrients to plants. Accumulations of Na^+, HCO_3^-, CO_3^{2-}, SiO_3^{2-}, or NaCl and Na_2SO_4 are common (Bohn et al., 1979). Excess sodium is often aggravated by nutrient deficiency where such essential elements as P, Fe, Mn, Zn of low solubility at high pH precipitate in soils (Desta Beyene 1983). On the other hand, harmful effects are produced with the increased concentration of certain specific ions including sodium (Levy et al. 1984). Complete crop failure could happen in some cases. toxicity.On the other hand, the low solubility of micronutrients value becomes a limiting factor.The combined effects of all these is partial or complete failure of crops and loss of land.

Distribution

Salt-affected soils have been around as products of their own formation history. They occur on low-lying topography of poor permeability that has hindered the leaching of dissolved salts. As a result, vast areas of salt-affected soils occur in the Afar, Oromia and Somali lowlands, specially the Lower Wabi Shebelle River Basin. In specific terms, salt affected soils cover a good portion of the Great Rift Valley. These include the northern Rift Valley as in the Awash River Basin; the central Rift Valley such as in and around Zuwai, Shala and Abaya lakes areas; the southern Rift Valley, the Omo River Basin, Lakes Turkana and Chew Bahir areas. Moreover, some are known to occur along many river basins such as Blate in the south, Dedesa in the north-west and Setit in the north of the country. Spots of saline soils in small perennial or seasonal river valleys are common phenomenon in the drier parts of the country. (EIAR 2006; FAO 1976, 1988; Girma and Endale 1996; Heluf 1985 1987; Mesfin 2001; Murphy 1959 and Szabolcs, 1979)

A central lesson that has been often forgotten is that irrigation and drainage are inseparable components of a single system. With failure to apply principles of irrigation, salts have accumulated from human-induced poor management of irrigation water. In the absence of drainage or the use of poor quality water, secondary salt build up has been the cause for the conversion of sizeable areas to saline and/or sodic soils at an alarming rate. Testimony to this is the thousands of hectares of land that were abandoned in the Upper, Middle and Lower Awash. Specifically, about 4,000 hectares of irrigated lands at Melka Sedi, are salt-affected. Substantial area has been abandoned because reclamation was not economically feasible once the threshold level beyond which there is no return was reached (Girma and Endale 1996; Heluf 1985; 1987; and Mesfin 2001). Considerable area at Metehara, Kesem, Kebena, Melka Werer, Gewanie, Millie, Abaya and others have also become salt affected with loss of productive land because timely corrective measures were not taken (EIAR 2006; Girma and Endale 1996).

A recent survey of small-scale irrigation in several regions has revealed the increased magnitude and intensity of build up from lack of soil-water-crop management (Heluf 1985; and 1987). Given the current drive for the increased expansion of the scheme the problem can reach alarming proportion unless knowledge-based timely appropriate measures are instituted. There is adequate warning from civilization that emerged in river valleys and deltas. Some died with ever increasing salt deposit in soils due to improper drainage and misuse of irrigation water. Thus, irrigated agriculture requires disciplined and knowledge-based management as key to the sustained utilization of soils in accordance with their nature. This applies not only to salt-affected soils, but to any soil for that matter to prolong their usefulness.

Opportunities and risks

Large-scale irrigation schemes have been around mainly for the production of cotton and sugar cane. New ones are being established in the main river valleys to exploit the new opportunity provided for remunerative returns. However, there could be the inclination to regard soils as something to be exploited for short-term profit rather than as resources which must be sustained in the long-run interest. Such a short-term view can produce serious soil related problems that may be difficult to effectively remedy, if at all.

Equally, small-scale irrigation is introduced with water harvested from streams, rivers, ground waters and lakes. Hence irrigation has been a blessing because it has helped mitigate threats from inadequate or unreliable rainfall. Therefore, it has increased intensification, diversification and multiple cropping. In the process, the increased use of improved cropspecies, fertilizer and compos as land restorative resources are promoted. The scheme has also offered job opportunity, increased management capacity, know-how, and skill of the operators. Most of all, many in the food insecurity areas have graduated out of poverty. Its fine-tuned sound managementcould allow production milestones without the habitat and soil ecology being disrupted but protected.

But, irrigation is a complex task. Itrequires skilled manpower with technical competence that can apply sound irrigation principles. Where this is absent or violated, water that contains salts under inadequate or ineffective drain agefavors secondary salt accumulation. It is aggravated when water is not uniformly distributed on the land and/or if insufficient water is applied to flush out salts.Then, irrigation becomesa curseunder both large and small-scale irrigation schemes.Ironically, once water, the prerequisite of production is obtained, getting rid of it is as crucial as assuring its continued supply. In reference to small-scale irrigation, drainage water from up-stream that contains salts could be re-used on a 'normal' soil. The down-stream soil could eventually be converted into salt-affected unproductive land. If water with salts returns to a river system or large water body, it contaminates pristine aquifers. When used for irrigation, such water with its quality diminished causes salts build up on the site or on land down-stream. The vicious circle can continue if the return flow is applied to other irrigated lands. The encroachment can be avoided with sound management of soil, quality of irrigation water, frequency and rate of water application, method of irrigation and drainage. Otherwise, poor irrigation management may defeat the original purpose at a time when a shift from traditional to modern agriculture is sought.

On the other hand, there is the introduction of famers-managed small-scale irrigation on soils that have various degrees of acidity. Some large-scale schemes are also underway on these easily erodible 'marginal" soils. Theyare poor in many essential nutrients but are rich in iron and aluminium that could be toxic. As a consequence, yields have not been strikingly even under fertilizers (Mesfin 1998). Thus, the key constraint has been soil acidity. That is why their amelioration by liming with soil fertility re-capitalizationand essential improved technologies is the first prerequisite for dividends. Conversely, with the proliferation of irrigated agriculture on these soils, the 'smoking gun' of erosion can be aggravated. In the absence of conservation-based sound management, the use of heavy machinery where the protective natural vegetation has been cleared causes compaction and pulverizes the soil. Then, when there is soil-laden flood, it is tempting to blame nature and easy to ignore the human role in making an area vulnerable to damage far more drastic than nature alone would cause. Sadly, the debt of humans to soil resources is often discovered after their degradation.

Improved management

All water used for irrigation contains salt. It may be a few milligrams in rainfall to over 1000 milligrams per liter in other waters. Then, irrigated agriculture is not simply enough to locate water, wet the soil and reap bounty. In tune with the enterprise to be embarked upon, it requires the efficient use of water under sound land and crop management. As a first step, the nature and extent of the problem, whether the soil is saline, or saline-sodic, or sodic must be determined since the interventions vary based on their properties. Equally, the quality and availability of irrigation water for crops and for leaching salts has to be known.The selection of the irrigation method to apply the amount of water that the soil can hold to meet the peak demand of the crop figures prominently.

Adequate drainage is necessary for the prevention and effective reclamation of salt affected soils. In its absence, no matter how much water and/or amendments are added, lasting reclamation is not possible. That is why irrigation and drainage are inseparable components of a single system. Thus, the presence of adequate natural or man-made drainage is a prerequisite such that threshold levels would not be reached. Information is also necessary on the inputs required, availability, and economic considerations. Further, the frequency and rate of water application have to be determined. Its effect on exchangeable sodium and other species must be assed for sound reclamation and to prevent toxicity effects on crops. No less, the effect of soluble salts on groundwater composition is an overriding concern. Care should also be taken such that return flow from drainage would not contribute to the salt content of a river downstream. All are important in selecting appropriate technology and sound management practices the can make the method of irrigation and reclamation cost-effective.

Land management

Proven solutions are around to preventthe dual problem of water logging and salt deposit from the introduction of irrigated agriculture. The first condition is proper land selection. Then the land must be surveyed and shaped to avoid water ponding and the accumulation of salts on low spots. The nature of the soil must also be known if there are significant differences in water intake characteristics or in the available water holding capacity. This is also vital for uniformity of irrigation water application. There is also a direct relationship between the use of water for irrigation and salt accumulation since dissolved salts do not evaporate. While it is possible to change soils to fit crops, the selection of proper irrigation method based on the nature of the soil and crop, the required amendment, the quality and amount of irrigation water to be used were not critically assessed (Girma and Endale 1996; Heluf 1985; 1987; and Mesfin 2001).

Either way, basin and border irrigation have been used on large scale irrigation schemes. Water that is plentiful and cheap has often been used in excess. When water was impounded or soil flooded, and in the absence of drainage water disposal outlet that anticipates salt accumulation, build up of the water table has caused increased salt over time in many state farms. Some farms have used furrow irrigation without salt conveyance water ways for drainage and leaching. This has caused salts accumulation due to evaporation. On the other hand, sprinkler irrigation is a new comer to the scene. The 'lateness' in its wide use is due to the high initial investment cost and the enormous power requirement for sprinkler head system. Further, a constant water supply that is clean and free of sand and debris is needed. It is now being successfully used in some private large scale agricultural schemes and sugar plantations. However, some problems could be encountered with the distortion of the sprinkler pattern and uneven distribution of water by wind. When the water sprayed is blown about, parts of the field may get too much water and others too little. Accordingly, there would be uneven salt accumulation in line with the irrigation water distribution. Yet, it may seem a paradox that drainage problems should occur on land that is considered semi-arid.

Under small-scale irrigation, open ditches or furrows are the common means of conveying irrigation water. But, the system should avoid crop damage on the portion of the field that is irrigated last. This means that it must be completed before it is time to start another round. It must also apply water at a rate that does not cause runoff or cause water to stand on the surface of the soil to cause salt build up. To this end, some appropriate tools include: proper land preparation, judicious use of amendments such as fertilizers, introduction and/or selection of salt-tolerant crops, and adequate natural or man-made drainage to leach soluble salts. It is also a common practice to watch plants for signs of moisture deficiency as a basis of supplying irrigation water. But, by the time the plants show signs of water need they may already be suffering. Instead of waiting for indication from plants, one can watch the soil. Periodic soil sampling can indicate the moisture status of the soil. Several inexpensive devices are also available that can be used by farmers. Either way, farmers must have some practical knowledge to determine amount of water to apply, when, and under what condition it is to be used to minimize salt concentration and provide adequate water for high production.

But, a problem of great economic importance to farmers arises when salts develop on good farm land. There is the encroachment of small-scale irrigation schemes even when the principles that guide good irrigation management are known (EIAR 1996). Its rapid expansion can become one of the major causes for a spiral loss of productivity in what should have been a flourishing agriculture. To begin with, where the size of the irrigation stream is not carefully controlled, salts accumulate due to seepage from unlined earth channels and ditches. Again, re-use of drainage water or rejoined water drained from irrigated lands increases the level of dissolved salts to affect downstream users. There is also concern that when reclaimed or waste water containing excessive dissolved salts is applied to soils, a 'normal' soil is converted to saline. As the water near the surface evaporates, salts are deposited.This must be reduced with adequate surface drainage. Still, proper planning of the time and conditions under which such water is allowed to rejoin the water downstream can minimize the possible impact.In essence, the problem can be improved under informed management as innovative as nature itself. If not, it will become the major, if not the only, cause of pulling the ground from under our feet.

Crop management

If the soil is not adapted to the plants, the plant could be adapted to fit the soil with recognition that various crops require different amount of nutrients, water and irrigation schedule. Much is now known about crop tolerance to salt (USSLS 1954).There are a number of indigenous salt tolerant crops, forages, shrubs and grasses that have tolerance to soluble salts and exchangeable sodium in soils. It is also possible to select, breed and adopt salt tolerant/resistant crop species with judicious use of input under good agronomic practices. Then, a list can be prepared for crops based on percentage yield decrease as a function of soil salinity i.e. the maximum allowable salinity without yield reduction**.** Such crops can be complimented by judicious agronomic practices with required appropriate production technology

There are also indigenous practices that can provide synergy with high dividends under small-scale irrigation. The carrying capacity of land and water use efficiency can be increased with mixed cropping. Haphazard and chaotic as the practice may seem, it offers vast benefits. It assures a more regular food supply than when a single crop is grown in pure stand. The total yield from crops with differences in maturities will be high with grater land use efficiency beyond unity. Stand mixtures of legumes with cereals (or the rotation of legumes with cereals) can help enrich soils with nitrogen. In addition, the varying rooting habits of the different crops permit nutrients to be tapped from various soil depths. No less, it minimizes the risk of crop failure due to adverse weather, incidence of diseases and pests. It is, therefore, befitting that traditional management practices be fine-tuned and promoted. The use of fallow to rest the soils or to 'recover' its fertility is now on the decline but needs to be re-instituted.

Much can be extrapolated from the use of compost whose wide use is now being accelerated for the restoration of soil fertility. Since organic matter promotes water infiltration to recharge the soil moisture, such storage can be considered as a bank account to be drawn by crops during periods of rainfall scarcity. It supplements irrigation without incurring cost. Even where there is no adequate drainage, the good soil structure fosters better leaching of salts while it allows the extensive reach of soil amendments used for reclamation. For instance, bermuda grass *(Cynodon dactylon)* has proved useful in the reclamation of abandoned soils with luxurious year-round growth in the Melka Sedi State Farm (Heluf 1985; 1987). Salt affected soils can also be fallowed. When followed by salt tolerant forage crop it can assist salt reclamation. The biomass produced could contribute to livestock rearing. On the whole, where land and crop management are interwoven, they create a win-win situation of increased production and soil resource conservation.

Nature and reclamation

Prior to the initiation of reclamation, the nature of the salt-affected soil whether saline non-sodic, saline-sodic and sodic, its cause and severity, the physical and chemical properties of the soil, the water quality, calcium carbonate and gypsum contents, the change expected after reclamation have to be known. Equally, the major factors that adetermine the water quality for irrigation have to be assessed. These are:

- the total concentration of soluble salts with effect on plant;
- the concentration of sodium and the proportion of sodium to calcium plus magnesium that increases soil deflocculation and impairs soil permeability;
- the concentration of bicarbonates that causes the precipitation of calcium and magnesium as carbonates that reduces the availability of nutrients to plants;

the occurrence of toxic elements such as sodium (Na), boron (B), lithium (Li), chloride (Cl), fluoride (F), (FAO, 1976, 1988. Szabolcs 1979, USSLS. 1954.

Further, there is the interaction of Ca, Mg, Na, HCO_3, and SO_4 in soils and irrigation waters with pronounced effects on the physical and chemical properties of soils. For the most part, the stress these soils include excess soluble salts, high saturation of the soil by sodium. Specific toxicity effects of certain ions such as Na, B and Cl; deficiencies of nitrogen given the scant vegetation for organic matter transformation, phosphorus due to the large quantities fixed as insoluble Ca^{2+} and Mg^{2+} compounds and by volcanic ash soils that are rich in silica, iron and aluminium,plus a host of micronutrients at higher pH values. Then, the reclamation of salt0affected soils will be based on their nature as elaborated below.

Saline non-sodic soils

The main problem of saline soil is accumulation of excess soluble salts. They contain soluble salts in quantities great enough to interfere with the growth and productivity of most crops. The ions including Ca^{2+}, Mg^{2+}, K^+, Na^+, Cl^-, SO_4^{2-}, HCO_3^-, and small amounts of NO_3^-. Calcium and magnesium are the dominant. Most contain substantial amount of calcium carbonate. They are flocculated due to their calcareous nature and have good permeability. It means these soils do not disperse but are stable in water and are easy to work. Therefore, the most common approach is leaching with surplus of good quality irrigation water to maintain permissible salt concentration in the root zone for a desired yield level. However, water with a moderate degree of salinity can also be used if drainage is adequate. (Rhoades et al. 1973 and Szabolcs 1979). Consequently, if adequate drainage is provided, the excess soluble salts can be removed by leaching where surface or sub-surface drainage is provided.

Saline-sodic soils

These soils contain both soluble salts similar to saline soils and high percentage of exchangeable sodium in quantities high enough to adversely affect the growth and productivity of the majority of crop plants. As a result, they possess the properties of both saline and sodic soils. The dispersing effect of exchangeable sodium may be counterbalanced by the flocculating effect of soluble salts present. Thus, unlike sodic soils, they are well-structured and are permeable to water making their physical condition much like those of saline soils. However, with the removal of excess soluble salts its property is markedly altered. The soil becomes similar to sodic soils and becomes strongly alkaline. It swells and disperses. It becomes unfavorable for the entry and movement of water and air, root penetration and tillage as is true for sodic soils. Thus, their reclamation is a challenge. To begin with, the dispersion of soils due to excess exchangeable sodium has altered their physical properties, particularly their aggregate stability. Therefore, it is the improvement of their permeability by applying amendments to remove sodium which is the first requirement.

Therefore, the reclamation saline-sodic soil does not start with leaching since it causes dispersion and impermeability due to sodium which finally converts it to sodic soil when the soluble salts are removed. As a result, amendments proceed leaching. Gypsum ($CaSO_4 .2H_2O$), a coagulating agent, is commonly used as a cost-effective source of calcium to replace sodium on the soil exchange complex. It increases infiltration and improves the permeability of soils. Once sodium is in the soil solution, it can be removed as sodium sulphate (Na_2SO_4) by impounding ample quantities of good quality water under adequate drainage. Others such as fallow that allows the generation of grasses and other vegetation have been demonstrated to be useful in the Melka Sedi plantation, the Middle Awash (Girma and Endale 1996; Heluf 1985; 1987). Compost that is inexpensive can bind salts when converted to organic matter also helps. Their modification can also be facilitated through innovative land and crop management.

Sodic soils

They contain sufficient exchangeable sodium that interferes with the growth of most plants. Sodium also becomes dominant through the precipitation of calcium and magnesium as carbonates. However, sodic condition is not accompanied by the high salt content that is characterized by saline condition with excessive amounts of soluble salts. Because of, sodium saturated soil is hygroscopic, it become oily, and dark brown when wet. The soils are deflocculated and if transported downward it develops a dense layer of low permeability. This means replenishing water to the root becomes increasingly difficult. On account of that soils become exceptionally compact and difficult to till. Others effects are restriction of roots penetration, water uptake and the toxic effects that sodium and others ions exert on plants. In addition to alteration of soil physical properties, Na can exert toxic effects on plants.

As is true for of saline-sodic soils, the reclamation of sodic soils does not start with leaching. Impermeable as they are due to their dispersed poor structure, impounding water helps little. Instead, it starts with the addition of amendments to replace exchangeable. Once sedum in the soil complex is removed it can be followed by leaching from the soil with the right amount of good quality irrigation water. While each type of amendment has a place in reclamation, the choice on the type and amount of amendment, however, depend upon the characteristics of the soil, the desired level of sodium replacement and economic considerations. Their effectiveness under different soil conditions is also governed by several factors. The principal ones are the pH and alkaline-earth carbonate content of soils.

On the whole, reversal of salinity or sodicity seeks a carefully planned and integrated long term strategy. This is even more pressing when sustainability comes to the forefront as is happening today. Therefore the areas of focus for thesustainable management of salt-affected soils include: organizing database; introduction, selection, and breeding of salt tolerant crop varieties. Correlation studies based on soil testing and plant analysis, improvement of livestock, pasture and forage, promoting the participation of stakeholders for timely delivery of amendments and other inputs in the specified quantity and quality; soil surveying, exploring, quarrying and processing of materials for use as amendments; formulating the required specifications of amendments; establishing quality standard for amendments and monitoring mechanism; promoting the participation of the private sector and others in their upkeep and/or reclamation are essential. The infusion of indigenous knowledge and practices with appropriate technology can also have a snowballing

On the way forward

Irrigation must be regarded not only in technical and economic terms but also in its social dimension. It is then possible to provide knowledge and timely technology to farmers and other stakeholders that are reluctant and fearful to abandon old ways due to perceived threats from unforeseen calamities.Then, people can respond to present challenges and meet changing needs. Otherwise, poor irrigation management may defeat the original purpose at a time when a shift from traditional to modern agriculture is sought.

Some areas of focus are: the development of appropriate soil-water-nutrient-crop management practices. The methods of reclamation; time, type, and rate of amendment to be applied, the effective duration of reclamation, their residual effect on water bodies and the economics of reclamation are fertile areas of research. Again, it is not enough to increase production unless post-harvest losses are reduced or cut. This is vital especially when it comes to perishables. Equally, effort to develop new teaching designs and concepts that accommodate subjects seldom taught in traditional curricula has to be strengthened. This will help cultivate graduates as agents of change. In this conjunction, hitherto animal-drawn tools and implements have to be improved to increase their efficiency and versatility in tune with the task to be performed, soils and farming conditions. This can enhance labor productivity and they must be sufficiently cheap to merit adoption.

In another note, past efforts to survey and map salt-affected soils were not comprehensive. But as an important entry point to their sound management, a tailored approach is necessary in partnership with the relevant stakeholders. The current inroads in the development of soil fertility map should be strengthened since there are now a number of laboratories that can perform reliable analysis of soil, plant, water, fertilizers etc. Using these facilities, the continuous analysis o fthe irrigation water resources into different water quality classes is a must. Meaningful interpretation of soil test valuescan also be made when it is correlated with the yield response obtained under a particular nutrient for a specific crop. The systematic collection, screening and selection of salt tolerant crop and pasture species is essential since their use is less costly than other reclamation exercise. In the final analysis, development-oriented long term research is necessary for the appraisal of selected soil characteristics over time. Such trial provides knowledge on the source and nature of the change. It is vital for the continued diagnosis, monitoring and improvement of the diverse salt-affected soils. Then, technologies that may take generations to work their way into the collective wisdom will be accepted based on their merit without delay. This means that the quality and quantity of research data generated has to be improved and the turn-around time minimized. It could be improved with increased capacity building especially skilled power, trial and demonstration sites. Upgrading of such facilities as greenhouses, laboratories equipped with efficient and appropriate instruments, analytical techniques are also essential. These are vital tools for the identification, appraisal, monitoring, evaluation and/or reclamation of salt-affected soils.

Finally, in the true spirit of participatory development, functional collaboration thatstrengthens the bond between the community, the private and public sector is essential as a'life-line'to overcome monumental challenges ahead. Then, it is possible to interweave various disciplines of agricultural and allied sciences to formulate and disseminate development-oriented packages of appropriate technology. Then, it is possible to provide timely encouragement to farmers and other stakeholders that could be reluctant and fearful to abandon old ways due to perceived threats from unforeseen calamities. This goes a long way to combat the poverty and environment degradation merry-go-round. Better still,irrigated agriculture can become a "panacea' with production bonanza to help attain food security. Therefore, the conservation-based development of the semi-arid areas can transform their 'problem' soils into "irrigated oasis" that would contribute to the national economy with the resource base sustained by a pleasant environment.

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