CGIAR Challenge Program on Water and Food (CPWF) and Comprehensive Assessment of Water Management in Agriculture (CA) Research Priorities

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November 2006

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Introduction and Scope

The purpose of this document is to outline research needs in the field of water management for agriculture emerging from the Comprehensive Assessment of Water Management in Agriculture (CA). Through a consultative process, several priority research areas were identified where the experts involved in the CA consider that existing knowledge is insufficient. These research priorities are expected to support the CGIAR Challenge Program on Water and Food (CPWF) in furthering knowledge on water and agriculture, by helping to shape the research areas under which the CPWF will be funding projects.

About the CGIAR Challenge Program on Water and Food

CPWF is an international, multi-institutional research initiative with a strong emphasis on north-south and south-south partnerships. The initiative brings together research scientists, development specialists, and river basin communities in Africa, Asia and Latin America to create and disseminate international public goods that improve the productivity of water in river basins in ways that are pro-poor, gender equitable and environmentally sustainable.

CPWF practices research for development. On-going research work exemplifies this emphasis, and illustrates the Program's mix of site-specificity, scaling up to the basin level, and the production of international public goods. Thus, CPWF funds and conducts research that is a mixture of basic, applied and adaptive research linked to dissemination of results.

The CPWF is working towards achieving: food security for all at household level; poverty alleviation through increased sustainable livelihoods in rural and peri-urban areas; improved health through better nutrition, lower agriculture-related pollution and reduced water-related diseases; and environmental security through improved water quality as well as maintenance of water-related ecosystems and biodiversity.

CPWF themes (see Table 1) are a means for addressing different aspects of the water and food challenge and serve to package information at different scales on issues related to water productivity. The CPWF research strategy concentrates its attention on five thematic areas.

At the system level, the CPWF looks at (1) **Crop water productivity improvement**, (2) **Water and people in catchments**, and (3) **Aquatic ecosystems and fisheries.**

Crop water productivity improvement takes the view that water productivity can be improved through technological and managerial innovation at the farm level. Hence it seeks plant-breeding solutions for agriculture located in areas affected by drought and saline soils. It studies integrated natural resources management and crop production at field, farm and agro-ecosystem levels. This theme promotes policies and institutions facilitating the adoption of crop water productivity improvements.

Water and people in catchments **focuses** attention at the catchment level. It is concerned with water, poverty and risk in upper catchments. It seeks innovations in improved water management and aims to enable people to benefit from the improved management of land and water resources.

Aquatic ecosystems and fisheries investigates environmental water requirements; to value ecosystem goods and services; and to seek innovative ways in which to improve the productivity of aquatic ecosystems through policies, institutions, and governance.

At the basin level, the CPWF looks at **Integrated basin water management systems**, which identifies appropriate technologies and management practices designed to enable IWRM. It seeks innovative institutional arrangements and decision-support tools and information that can help with the establishment of this managerial strategy.

At the global level, the CPWF looks at **Global and national water and food systems**, which examines water, its management and use at the broadest of possible scales. Hence, globalization, trade, macro-economic and sectoral policies have an important bearing on water, how it is used, and its productivity. This theme is concerned with the kinds of investments and financing for agricultural water development and water supply that may improve water productivity or, indeed, hinder it. This theme area also recognizes that at international levels, the management of water resources is complex and therefore seeks to understand how best to formulate appropriate policy and institutions to deal with this complexity. The theme also considers changes in the global water cycle.

About the Comprehensive Assessment of Water Management in Agriculture

The CA aims to critically evaluate the benefits, costs, and impacts of the past 50 years of water development and current challenges to water management. The CA asks how water for food can be developed and managed to help end poverty and hunger, ensure environmentally sustainable water-agriculture practices, and find the balance between food and environmental security. It assesses innovative solutions and explores consequences of potential investment and management decisions. A first phase focused on gap-filling research. Building on this, the second 'synthesis' phase focused on an assessment of knowledge and experience to guide investment and management decisions in the near future in order to enhance food and environmental security.

The synthesis phase was designed along the lines of the Millennium Ecosystem Assessment and the Intergovernmental Panel on Climate Change processes with the aim of being both scientifically rigorous as well as an open forum for knowledge sharing. Chapter teams were formed comprising of lead authors, contributing authors, and a broader network, and in some cases, comprising up to 100 people per chapter. To stimulate participation, each chapter had at least one workshop, and online consultation process, and two independent reviews. Cross-cutting meetings involving members from all chapters were held to ensure integration. All chapters have undergone an extensive peer-review process.

Over the past five years the CA has been engaged in a complex process of dialogue, partnership, research, synthesis, review and outreach. The CA has brought together over 700 researchers, practitioners, development professionals, water users and policymakers from around the world. A diverse group of stakeholders, experts from different continents, disciplines, and institutions have shared their knowledge, experience and views on key issues.

Results of the CA process are documented in the report entitled *Water for Food, Water for Life: the Comprehensive Assessment*, to be published by Earthscan in late 2006. Additional outputs from the research phase are published in a book series by CABI, a Research Report series, highlighting work by partners, and several academic journal publications derived from CA supported research. The CA has also supported 30 students. The CPWF is one of the key clients of the CA.

Methodology & Structure of Document

The information on which this document is based was derived from the larger CA process, including feedback and debate - through workshops, online discussions and reviews – on issues that had been raised by networks of individuals stemming from academia, government ministries, NGOs and other local organizations associated with each of the CA chapter topics (see Table 1), peer review teams and review editors for each chapter. These groups commented on the CA chapters throughout the drafting process from outline to final drafts. The research priorities included in this document have benefited from that process. Ultimately, they have been identified through a collaborative process involving the CA secretariat and the lead authors of the CA synthesis chapters, with input from the CPWF secretariat, Basin focal project coordinators and others involved in the CPWF process. The priorities are considered to be the most significant knowledge gaps and research priorities in the various CA topics, as spelled out and justified in the CA chapters.

In some cases, the gaps and priorities were similar across chapters, and have thus been compiled and merged. The source of the priority and justification (CA chapter) has been included where possible. Priorities have been loosely clustered into sub-thematic groups within the five CPWF themes, but there has been no attempt to rank individual priorities. As the CPWF themes are not directly matched with the topics of the CA chapters, the categories have been selected mostly for the sake of user-friendliness of the document. A quick reference to priorities according to CA chapter theme can be found in Table 2. Acronyms are included in Table 3.

Each research priority has been assessed vis-à-vis each of the nine CPWF Basins. One (+) indicates that the priority is relevant in the basin, two (++) indicates that the priority is highly relevant in the basin. Where no (+) is present, the research area is not considered a priority for that basin. These are indicative only and require more discussion within the basins.

Acknowledgements

The authors would like to recognize the efforts of the CA Coordinating Lead Authors and Lead Authors and the CPWF secretariat in the preparation of this document. In addition, the following individuals deserve special mention: Mobin-ud-Din Ahmad, Kim Geheb, Francis Gichuki, Sophie Nguyen Khoa, and Jorge Rubiano.

Table 1. CA Chapter Topics and CPWF Research Themes

Comprehensive Assessment of Water Management in Agriculture	Challenge Program on Water and Food
Chapter Topics:	**Themes:**
Basins	Theme 1: Crop-water Productivity Improvement
Ecosystems	
Fisheries	
Groundwater	Theme 2: Water and People in Catchments
Irrigation	
Land	
Livestock	Theme 3: Aquatic Ecosystems and Fisheries
Marginal Quality Water (MQW)	
Policies and Institutions (P&I)	
Poverty	Theme 4: Integrated Basin Water Management Systems
Rainfed	
Agriculture	
RiceScenarios	Theme 5: The Global and National Food and Water Systems
Water Productivity (WP)	

Table 2. Quick Reference to Priorities by Topic

Topic	Priority Number
Rainfed	1, 11, 23, 38
Irrigation	6, 15, 16, 32, 36, 40, 46, 47, 60
Groundwater	14, 16, 39, 40, 41, 45
Basins	42, 43, 44, 51, 56
Livestock	22, 28, 48
Rice	2, 3, 49, 64
Fisheries	7, 31, 35, 37, 55
Land	13, 17, 18, 29, 63
Ecosystems	4, 23, 30, 31, 33, 34, 50, 52, 62
Scenarios	61, 63, 65, 66, 67, 68
Poverty	1, 12, 16, 24, 26, 27, 32
P&I	25, 47, 54, 56, 57, 58, 59
MQW	4, 5, 19, 20, 21, 53
WP	8, 9, 10

Table 3. Acronyms

CA	Comprehensive Assessment
CGIAR	Consultative Group on International Agricultural Research
CPWF	CGIAR Challenge Program on Water and Food
CWANA	Central West Asia and North Africa
IMT	Irrigation Management Transfer
IWRM	Integrated Water Resource Management
MDG	Millennium Development Goal
MQW	Marginal-quality water
NERICA	New Rice for Africa
P&I	Policies and Institutions
QTL	Quantitative Trait Loci
SSA	sub-Saharan Africa
WARDA	African Rice Centre
WTO	World Trade Organization
WUA	Water users' association
Moz	Mozambique

Acronyms for Basins

A	Andean System of Basins
IG	Indo-Gangetic River Basin
K	Karkheh River Basin
L	Limpopo River Basin
M	Mekong River Basin
N	Nile River Basin
SF	Sao Francisco River Basin
V	Volta River Basin
Y	Yellow River Basin

List of Research Priorities – Key Phrases

CPWF Theme 1

1. Improve the productivity of rainfed and irrigated agriculture for poverty reduction
2. Water scarcity in rice production
3. Rice productivity increases in rainfed and unfavourable environments
4. Long-term impacts of using marginal-quality waters on the soil-plant-aquifer system
5. New crop genotypes of increased salt-tolerance and efficient use of saline water
6. Large-scale irrigation systems
7. Methods for the valuation of fishery resources
8. Water productivity as the value or ecosystem services derived per unit of water use
9. Understand and diagnose constraints to basin water productivity

Adoption, Impact and Up-scaling

10. Lessons on adoption, non-adoption and impact of water productivity enhancing strategies
11. Scaling-up and scaling-out of best-bet options for enhancing agricultural productivity and incomes
12. Impediments to replicating local successes derived from particular farming systems

CPWF Theme 2

13. Managing soil constraints to improve water cycling and productivity in landscapes
14. Groundwater and poverty reduction
15. Irrigation investments to mitigate poverty
16. Irrigation in sub-Saharan Africa
17. Small-scale agricultural livelihoods that prevent or mitigate land degradation under high population density conditions
18. Mapping and assessment of extent, rates and drivers of land degradation and water scarcity
19. Cost-effective and innovative wastewater treatment technologies and methods
20. Effectiveness of measures, such as health risk reduction, wastewater application and human exposure control in reducing the level of pathogens and other contaminants in farms, markets and households
21. Exposure and health impacts to wastewater affected populations
22. Quantify livestock use of and impact on water resources
23. Institutional mechanisms to resolve issues of environmental services, payments
24. Concrete institutional arrangements that help enhance access for those without title to land and water
25. Research on how to enhance equity, including gender issues, poverty and corruption
26. Negotiation frameworks to bring different disciplines and stakeholders together
27. Participatory studies that directly involve members of water user associations
28. Gendered approaches for improving food production and decreasing poverty in pastoral systems

CPWF Theme 3

29. Livelihood and ecosystem impacts of water interventions at the catchment scale
30. Links between agricultural management in terrestrial systems and hydrology
31. Behaviour and responses of multi-species fish communities to changes in water availability
32. How to reduce the negative social and environmental costs of irrigation investments
33. Understand the resilience and dynamics of vital ecosystems
34. Developing mechanisms for dealing with trade-offs over space and time, and developing and understanding management practices that enhance social capacity to cope with surprising change
35. Development and application of alternative methods for enhancing fish production.
36. Enhance positive and mitigate negative environmental impacts derived from water management
37. Research-based methods for encouraging the participation of fisher communities in management

CPWF Theme 4

38. Develop integrated water management at the micro-catchment scale
39. Assess agro-chemical pollution of aquifers in developing countries
40. Development of practical methods of groundwater recharge that protect the quality of both groundwater and aquifers
41. Large-scale, research-based, regional assessments of groundwater circulation and quality on aquifer systems that are being rapidly developed
42. Understanding and quantifying water recycling through the basin
43. Processes that lead to the over-commitment and overbuilding in river basins
44. Impacts of inter-basin transfers
45. Identify the extent to which aquifer systems will be an effective and reliable buffer in the context of drought management and climate change
46. Development of practical systems of assessing supply availability and registering current water-use rights among users at the basin level
47. Implementation of IWRM
48. Research-based policy options for integrating livestock into integrated river basin management
49. Ecosystem services of irrigated rice environments
50. Multiple uses of water
51. Characterisation and quantification of environmental services in a basin context
52. Ecosystem services for food production

CPWF Theme 5

54. Studies of different structural options to manage river basins
55. Intersectoral policy framework adapted to inland fisheries
56. Action research to understand, enable and facilitate polycentric governance – where appropriate – in river basins

57. Support the process of institutional reform in agricultural water management

58. Studies of outcomes and performance of IMT reforms 10-15 years after implementation

59. Empirical research into 'rent seeking' and its impact on water resource use and management

60. Development of effective institutional, economic and governance mechanisms to sustain public and private irrigation

61. Impact of investments in agricultural water management on national economies and poverty reduction

Global Change Research

62. Links between agricultural water use and climate change

64. Impacts of rice production on climate change

65. Future impact of higher energy prices on water use

66. Future impacts of changing diets on water demand and use

67. Future impact of water productivity improvement on water quality

68. Future impact of trade and world market prices on agricultural water use

CPWF Theme 1

Under the first CPWF Theme – 'Crop-water productivity improvement' – the following CA topics are relevant: water productivity, irrigation, rainfed agriculture, rice, MQW. Overlap with livestock, fisheries, poverty, ecosystems

1. Research into how best to *improve the productivity of rainfed and irrigated agriculture for poverty reduction.*

   Projections of agricultural yields and water productivity improvements from the CA indicate large opportunities to reduce the relative increase in consumptive water use in both irrigated and rainfed agriculture, but the evidence is incomplete. More complete knowledge is important because productivity improvements could reduce the future consumptive water use in agriculture significantly. Recent established but incomplete analyses show that (average) current water productivity for vegetable-based foods (grains, vegetables, fruit) amount to on average 0.5 m^3/1000 kcal (which translates to approximately 1000-1500 m^3/ton dry matter). Evidence suggests that the high risk for water related productivity loss makes farmers risk averse, which in turn determines farmers' perceptions on investments in other production factors (such as labor, improved seed and fertilizers). Further information is required on (1) how to increase yields without increasing risks (and costs) and (2) what other drivers limit farmers' attitude to risk (market access, etc.).

   Established but incomplete evidence shows that there is a large untapped potential in rainfed agriculture in developing countries, even in water-scarce semi-arid and dry sub-humid regions. This is because yields oscillate around 1-2 t grain/ha compared to attainable yields of over 4-5 t grain/ha. An area of focus is the dry sub-humid and semi-arid region, subject to the largest challenges of poverty, water management and hunger, and in which the lowest yields and the weakest productivity improvements have been experienced over the past 50 years. Here, yields oscillate in the region of 0.5-2 t/ha, with an average of 1 t/ha in SSA, and 1-1.5 t/ha in CWANA for the rainfed agriculture where the lowest yields are experienced.

   In addition, there are hydrological and agro-ecological limits to the expansion of irrigated agriculture, meaning that rainfed agriculture still remains an important source of food and income for a substantial number of poor people in developing countries. What, then, are the appropriate water management, technological, institutional and organizational interventions required to raise the productivity of rainfed agriculture for effective poverty reduction?

   Equity issues also arise between geographical areas, and inter- or intra-households. Investment in agricultural water management will inevitably be better suited to some regions than to others, and hence geographical inequity is generally unavoidable. For instance, depression of output prices for significant numbers of poor rainfed net food producers following the introduction of irrigation in one location is a concern. Productivity raising technologies such as irrigation have equitable on-farm benefits when: they are scale-neutral and can be profitably adopted on farms of all sizes; land is equitably distributed with secure ownership or tenancy rights; efficient input, credit and product markets exist, giving all farms access to information, inputs and prevailing prices; and policies do not discriminate against small farmers and landless laborers (e.g., mechanization subsidies or anti small-scale biases in research and extension). These conditions are rarely met by irrigation and it will usually reduce equity between households. Larger and relatively 'resource-rich' irrigators will benefit most, even if the poor usually still benefit in absolute terms.

Many irrigated areas in both medium- and large-scale systems continue to remain home to a large number of the poor. This is partly due to low productivity resulting from lack of access to water, particularly in downstream areas. There are real opportunities to reduce poverty among the many poor people who are not engaged in irrigated agriculture. Ensuring a balance in national water policy is one of the principal challenges that developing countries face. New strategies that improve the productivity of water in both irrigated and rainfed agriculture, and ensure access to water and technologies by the poor are required. Some assert that there is a need to promote comprehensive approaches and get people to avoid sectoral approaches, not only on the grounds of inefficiency and unsustainability, but because they are likely to promote inequity. Research needs to be centered on small farm holders. It is critical, in particular, to create awareness among governments of the significance of water in the resources base and the need for its protection not only as a sustainable strategy for economic growth and development but also as a critical measure for poverty alleviation.

[Source: Rainfed Poverty Chapters]

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2. Research into *water scarcity in rice production*, comprising:

(a) Mapping the extent and quantifying the magnitude of water scarcity in rice-based ecosystems;

There is no systematic inventory, definition or quantification of water scarcity in rice-growing areas. It has been roughly estimated that by 2025, 15-20 million ha of irrigated rice will suffer some degree of water scarcity. This gives us a rough idea of the extent of scarcity. But on the ground, scarcity problems are different – growing rice in arid environments, competition for a limited supply of water, or lack of infrastructure to deliver water to rice farmers. Each case needs a different type of response.

(b) Research into the development and adoption of water-saving technologies tailored to regional needs - what will work where? What will be sustainable? What is most likely to be appropriate?

Different water scarcity settings require different water savings approaches. Research is needed to tailor these approaches to different situations in light of water productivity objectives, poverty and ecological impacts, and considering factors that lead to adoption.

For example, aerobic rice shows potential as a response to scarcity in irrigated settings It is estimated that aerobic rice systems are currently pioneered by farmers on some 80 000 ha in north China. However, the development of aerobic rice systems for irrigated environments is in its infancy and more research is needed to develop high-yielding aerobic rice varieties and sustainable management systems.

While comparatively much work has been done on the development of technologies to increase crop productivity under water scarcity, little attention has been paid to long-term sustainability and to the reduction of negative environmental impacts of rice production systems that use less water. Studies are needed on the relationships between the use of organic and inorganic fertilizers and crop residue management on the one hand, and yield sustainability, greenhouse gas emissions and pathways of nutrient losses on the other. The effectiveness and environmental impacts of fertilizer management technologies such as site-specific nutrient management, slow-release fertilizers, and deep placement, need to be evaluated under various scenarios of water availability. Little is known about changing pest and disease dynamics when field conditions change from water-abundant to water-short, although initial reports suggest an increase in soil-borne pests such as nematodes.

[Source: Rice Chapter,

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3. Research into *rice productivity increases in rainfed and unfavorable environments*: develop technologies that integrate genetic improvement with natural resource management (water, soil, crop) for (a) drought-prone, (b) flood-prone, and (c) salinity-affected environments.

With the onset of climate change and other stresses, the need to identify varieties and techniques that will promote productivity increases in rainfed and unfavorable environments continues to be germane. While certain progress has been made, further advances are needed.

Drought. Most progress so far has come from the development of short duration varieties that escape drought at the end of the rainy season. But in the last decade, substantial genetic variability for grain yield under drought stress has been documented in both cultivated Asian rice, *Oryza sativa,* and its hardy African relative, *Oryza glaberrima.* Drought tolerance has been demonstrated to be moderately heritable, with repeatability similar to that of yield in non-stress environments. New breeding approaches and improved screening methods are advancing the development of drought-tolerant varieties and are being extended to national programs. The most promising strategy for developing drought-tolerant yet high-yielding cultivars is to combine selection for yield potential under favorable conditions with managed stress screening for yield under treatments that impose severe stress bracketing the drought-sensitive flowering period. This approach is resulting in the development of both lowland- and upland rice varieties that have improved tolerance to periods of severe water stress during the sensitive flowering and grain-filling stages while retaining the ability to produce high yields when water supplies are not limiting. Breeding efforts need to be specifically directed to well-defined target environments. Two specific examples for upland environments are “aerobic rice” and NERICA (New Rice for Africa). Aerobic rice is higher yielding than traditional upland varieties and combines input responsiveness with improved lodging resistance and harvest index. These new varieties are specifically designed for non-flooded, aerobic soil conditions in either rainfed or water-short irrigated environments. At the African Rice Centre (WARDA), breeders started crossing *Oryza glaberrima* with *Oryza sativa* species in the mid-nineties to combine the ‘toughness’ of the former with the productivity of the latter. These crosses have subsequently been named NERICA and aim to combine resistance to local stresses with higher yield, shorter growth duration, and higher protein content than traditional rice varieties. NERICA is specifically targeted at the upland and dryland areas of SSA.

Flooding. Though breeding for submergence tolerance and enhanced yield in flash-flood areas has been going on for over three decades, only a few tolerant lines with improved agronomic characteristics have been developed so far. For flash-flood areas, some tolerant landraces were discovered that can withstand complete submergence for 10-14 days, such as FR13A, FR13B, Goda Heenati, Kurkaruppan, and Thavalu. A few submergence-tolerant breeding lines with improved agronomic characteristics have now been developed by transferring this tolerance into semi-dwarf breeding lines. Fast progress is being made with the development of submergence tolerant lines using marker-assisted selection. For deepwater areas, elongation ability of leaves and internodes are essential to keep pace with the rising water and to escape complete submergence. Some breeding progress has been made and a few new lines with reasonable yield and grain quality have been released. Recently, three main Quantitative Trait Loci (QTL) for elongation ability were identified. Fine-mapping and tagging of these QTLs should facilitate their efficient incorporation into modern popular varieties through marker assisted selection.

Salinity. Despite its sensitivity to salinity, considerable variation in tolerance exists in rice. Combining new efficient screening techniques with conventional, mutation and anther culture techniques, salinity tolerance was successfully introduced into high-yielding plant types. Some newly released varieties have demonstrated more than 50% yield advantage over current salt-sensitive varieties. Breeding cultivars with much higher tolerance is possible if component traits are combined in a suitable genetic background. The opportunity to improve salinity tolerance through the incorporation of useful genes and/or pyramiding of superior alleles appears very promising. A major QTL, designated '*Saltol*', was recently mapped which accounted for more than 70% of the variation in salt uptake in this population. Marker-assisted backcrossing is currently being used to incorporate this QTL into popular varieties that are sensitive to salt stress.

[Source: Rice Chapter]

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4. Research into the *long-term impacts of using marginal-quality waters on the soil-plant-aquifer system* as well as the economics of marginal-quality water use projects.

Except for a few comprehensive national assessments conducted in Vietnam, Pakistan, and India, scattered information exists on volumes of raw or diluted wastewater currently used in agriculture, which is a limitation for projecting estimates of future use. Another challenge for data collection and comparison is the lack of universally accepted typology. In some cases, information regarding agricultural use of wastewater may actually be available, but not easily accessible due to government policies, or because it is found in grey literature in local/national languages. Approximate estimates of the global extent suggest that at least 2 million ha are presently irrigated with untreated, partly treated, diluted, or treated wastewater.

Some of the implications of using wastewater for irrigation are not known with certainty. Farmers, consumers, and researchers will gain knowledge regarding the potential impacts of specific constituents as experience with wastewater use increases. Given the inherent uncertainty and the potential social costs, public agencies must adopt the precautionary principle when designing policies regarding wastewater use. Policies should minimize the potentially harmful long-term impacts, even when those policies might limit the near-term financial gains to farmers and consumers. Public awareness campaigns might be helpful in gaining support for policies that reflect the precautionary principle. Special efforts will be needed in areas where many farmers or consumers are not literate and where farmers depend on wastewater to support their livelihoods.

[Source: MQW Chapter; Ecosystems Chapter]

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5. Research on the development of *new crop genotypes of increased salt-tolerance and efficient use of saline water.*

Public agencies can motivate farmers to improve the management of saline and sodic waters. Pertinent policies include requiring farmers to re-use or dispose saline drainage water within their farming operation. Water quality agencies might limit the discharge of saline drainage water to surface streams or enforce ambient water quality standards pertaining to constituents found in saline drainage water. In many areas, enforcement of water quality standards will require farmers and water user associations to reduce the discharge of saline drainage water. Public research and development of new methods for utilizing saline and/or sodic waters also will be helpful in improving management.

More research is needed regarding the optimal management of salt-tolerant crops, particularly when combining irrigation waters of high and low salt content. Blending of irrigation waters might be appropriate in some applications, while sequential re-use might be appropriate in others. Improvements in extensions services are needed also to inform farmers about new methods for utilizing saline/sodic waters. There has been a steady increase in the concentration of salts in sewage, soils, and aquifers in many areas of the world. There are no inexpensive ways to remove the salts once they enter the sewage. Governments and farmers are coping with the problem by means of several parallel approaches consisting of reduction in salt content of supplied water and/or treated effluents, reduction of salt addition during industrial and residential use of water, reduction of evaporation losses during wastewater storage, use of drip irrigation methods, adequate drainage of irrigated fields, discharge of the salty first-flood waters of the rainy season, soil application of amendments supplying calcium, and planting salt-tolerant crops.

Considerable variation (almost 10-fold) exists among crops for their ability to tolerate saline and sodic conditions. Therefore, selection of crops suitable for ambient saline and sodic conditions is essential to produce economically acceptable yields. In addition, factors such as the type and concentration of salts, soil type, rainfall amount and distribution, groundwater level and quality, and irrigation management practices must be given due consideration when irrigating with saline and/or sodic waters. Irrigation with saline water may also improve the quality of some crops as the sugar content in sugar beet, tomato, and melon is increased.

[Source MOW Chapter]

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6. Research on *large-scale irrigation systems.* In particular, more information is sought on the management, technological and institutional adaptation required in large irrigation schemes to:

(a) improve water productivity (improve economic output, save water) by upgrading canal systems and management systems;

(b) enhance positive and minimize or mitigate negative environmental and health impacts, and:

(c) promote institutions that can adapt to changing demands of the agricultural community and broader society.

Large-scale irrigation remains important for food security, employment, economic growth, environmental sustainability and poverty alleviation. Yet, many large-scale public irrigation systems fall below their