THE WEIGHT OF THE WORLD ON THE SHOULDERS OF SOIL SCIENCE: AMAZING NEW LINKAGES BETWEEN SOIL, WATER QUALITY AND EXTREME DROUGHT CONDITIONS AND WHAT IT MIGHT MEAN FOR OUR FUTURE FOOD SECURITY

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INTRODUCTION

This paper is overwhelmingly focused on linkages between soils (salt-affected and acid sulfate soils), water quality and extreme drought conditions in Australia, however the international context is important, especially for southern Africa. Climate variability and change are important considerations for the sustainable management of Australia's and southern Africa's water resources and hence future food security. The current drought in south eastern Australia is officially the worst on record, with minimal inflows to the Murray River and Darling River systems (Figure 1 - part of the so-called Murray Darling Basin or MDB). The main impact is clearly on water shortages and decline in water quality, which has resulted in water restrictions in most major population centres, but management strategies have also focused on ecosystem stress and salinity issues.

By about 2050, the world will need to be producing twice as much food as it does now, from about the same amount of soil and water. In many parts of the world but especially in the MDB, there is a distinct danger that traditional soil science, agronomy, pasture science and horticultural resources are being diverted away from food production to solve the declining land and water availability issues (i.e. in favour of alternative engineering solutions). Hence, this paper will briefly address the following issues:

- The critical role of salt-affected/acid sulfate soil management, both in the context of the current extreme drought and the likelihood that such conditions may become more frequent, widespread and intense.
- The need (and opportunity) to rethink soil management for food security in Australia and worldwide given the growing understanding of the importance of salt-affected/acid sulfate soils, both as a sink and source of chemical contaminants.

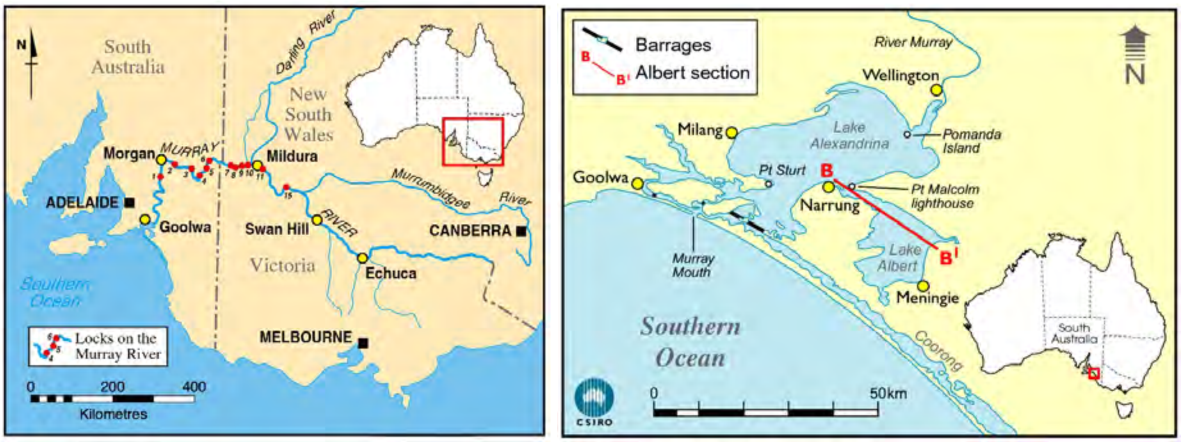

Figure 1. Locality maps showing part of the Murray River and Darling River systems in the Murray Darling Basin (MDB) along with locks on the River Murray (left map) and barrages, which were constructed to keep out sea water from the Lower Lakes (right map).

Salt-affected and Acid Sulfate Soils

Before we can manage salt-affected and acid sulfate soil (ASS) landscapes, we first have to define the type of soil-landscape based on the hydrological characteristics and the category of salt-affected soil from its dominant geochemical properties. Salt-affected soils and ASS form under the following vastly different environmental conditions under the influence of diverse hydrological, morphological, geochemical, mineralogical and physical processes:

- Groundwater Associated Salinity (GAS) comprises salt-affected soils in rain fed areas that have direct or capillary contact with saline groundwater watertables, and categories defined by the following hydrological and geochemical environments: (i) Primary (natural) or Secondary (anthropogenic) , (ii) Alkaline (sodium carbonate dominant, pH >9), (iii) Halitic (sodium chloride dominant), (iv) Gypsic (gypsum / calcium sulfate dominant) and (v) Sodic (high exchangeable sodium percent on clay surfaces).
- Non-groundwater Associated Salinity (NAS) comprises salt-affected soils in rain fed areas that have no direct contact with saline groundwater watertables, and with categories defined by the following soil chemical environments: (i) Sodic (ESP ≥5) and (ii) Saline (ECse ≥2 dS/m) conditions in the solum (A- and B-horizons, typically <1.2 m deep).
- Irrigation Associated Salinity (IAS) comprises salt-affected soils in irrigated areas with shallow (surface IAS) or deep (subsoil IAS) saline watertables.
- Inland and coastal Acid Sulfate Soils (ASS) are the common name given to all those soils with soil materials affected by iron sulfide minerals. These soils may either contain sulfuric acid or have the potential to form sulfuric acid in amounts that have a lasting effect on the main soil characteristics (Pons 1973) or cause deoxygenation or release contaminants when the sulfide minerals are exposed to oxygen. In general, the following two main genetic types ASS materials are recognised (Fanning 2002):
    - Potential or unripe ASS materials containing pyrite and/or monosulfides that are still waterlogged (i.e. contain sulfidic or monosulfidic materials).
    - Actual, active or raw ASS material containing sulfuric acid and pyrite at shallow depths (sulfuric material).

However, it is impossible to separate the effects of salinity totally from those of ASS (especially those with sulfuric materials) as they go hand in hand, while the level of salt that might be present in an ASS is of utmost importance in determining how certain subtypes of ASS will behave from a physical and chemical point of view. The application of our work to solve real agricultural and environmental challenges associated with salt-affected/acid sulfate soils and water quality issues in Australia, Iraq, China and Brunei has occurred at several levels (e.g. Fitzpatrick 2008; Fitzpatrick and Shand 2008). Our approach and procedures developed over two decades has been to:

- Identify the best set of soil and landscape field indicators for a region.
- Construct appropriate 3D and 4D mechanistic models of soil-regolith and water processes that explain and predict the processes giving rise to geo-chemically variable salt-affected soils using the toposequence approach (soil landscape cross-sections), which integrates pedological, hydrological, geological, biogeochemical and mineralogical information.
- Publish easy-to-use pictorial manuals that incorporate field indicators and mechanistic models to be used by land managers and which provide land-use options that help prevent the spread of soil salinity. The paper highlights case studies of the author and co-workers involving all types of salt-affected/acid sulfate soils (GAS, NAS, IAS and ASS).

Soil and landscape field indicators

Field indicators linked to landform elements are useful for identifying salt-affected soils and increasing awareness of the extent of salinity among landholders and regional advisers. Standard descriptive soil indicators such as visual indicators (e.g. colour) and consistency are often used by farmers, regional advisers and scientists in the field to identify and report attributes of soil quality (Fitzpatrick *et al.* 1999). For example, soil colour can provide a simple means to recognise or predict salt-affected, wetlands caused by poor drainage providing an alternative to the difficult and expensive process of documenting saline watertable depths to estimate water duration in soils. Visual indicators of salinity may be obvious (e.g. white salt accumulations on soil surfaces) or subtle (e.g. subsoil mottling patterns, strong pedality). Analytical indicators include electrical conductivity (salinity) and dispersion (sodicity). Combining descriptive and analytical indicators has provided vital information about soil-water processes leading to improve management and remediation of saline land, as demonstrated in several case studies from Australia, China and Iraq (Fitzpatrick and Shand 2008).

Hydro-pedologically based toposequence models
To understand the lateral linkages and relationships between soil and landscape indicators (soil profile features), we used the systematic structural approach to characterize soil-regolith features at different points along toposequences (Fritsch and Fitzpatrick, 1994; Brouwer and Fitzpatrick, 2002; Fitzpatrick *et al*. 2003). Colour photographs of typical profiles at different parts down the toposequence are used (Figure 2).

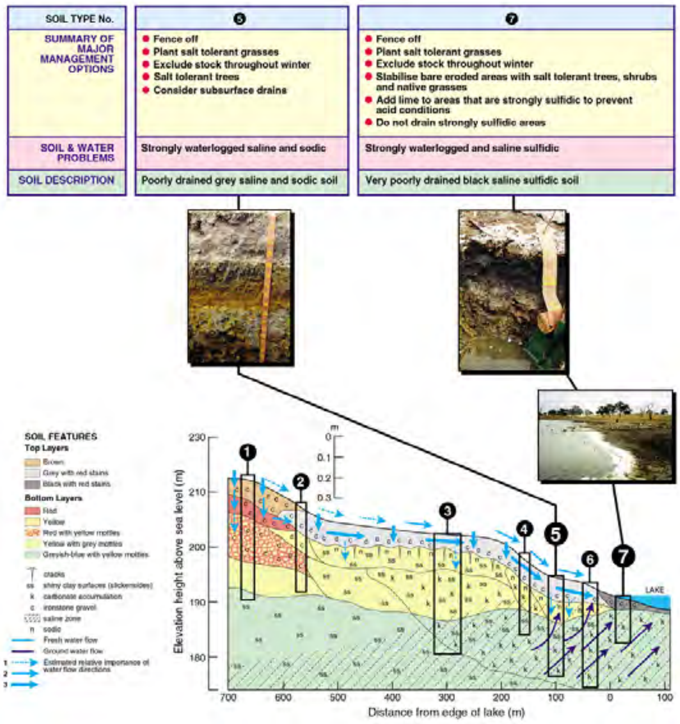

Figure 2. Sequence of soils down a slope (two of the seven soils are illustrated) linked to a 3D mechanistic model of soil and water processes with summaries of management options associated with each soil type from Woorndoo (Fitzpatrick et al. 2003).

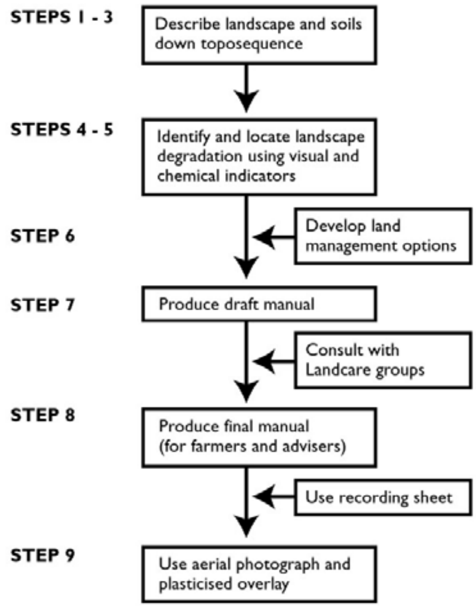

***Figure 3**. Flow diagram showing steps involved in developing manuals for land management (from Fitzpatrick et al. 2003).*

Briefly, we identified and described in the field, by depth interval, in all profiles along the toposequence, all relevant soil properties, including texture, coarse fragments, structure, matrix colour and mottling. In the office were added chemical and mineralogical properties. Toposequence cross-sections were then drawn that identified uniform layers that contain individual, or sometimes several soil-regolith properties. Subsequently boundaries were drawn around these layers. Each cross-section mapping unit or layer delineated is called a soil feature. A soil feature thus represents a limited range of one or more soil-regolith properties. The key soil-regolith features that help recognise and explain soil formation and interactions between different parts of the toposequence were grouped into the same soil systems using concordant relationships: i.e. where there is a concordant relationship spatial distributions and boundaries mostly coincide, and hydrological processes, geochemical processes and/or parent material will be the same. Soil features were separated into different soil systems using discordant relationships; in such cases spatial distributions show no or only partial overlap, boundaries do not coincide but touch or cut cross each other, and processes and/or parent material will be different (Figure 2).

Each soil layer displayed in the cross-section or toposequence was then linked to past or present soil and hydrological processes. The *descriptive process model* characterizes relict (past geomorphological processes in development of deep weathering and erosion) and current saline, alkaline, sodic, sulfidic or sulfuric soil forming processes in order to help develop practical solutions for ameliorating soils at farm scale. The *descriptive model* is used as the precursor or framework for developing the *explanatory model* (3D) shown in Figure 2, which represents current soil salinity (hatching), salt groundwater flow (dark blue arrows) and freshwater flow (light blue arrows). If required, the *explanatory model* in turn is used to develop the *predictive model* (4D). Consequently, the predictive model (4D) consists of a collage of figures, which illustrates several evolutionary cycles of soil-regolith events (e.g. Fitzpatrick et al. 2008a,b).

Predictive models and maps for Acid sulfate soils

The River Murray system (Figure 1) is a good example of a system, which is not only highly stressed but has been highly managed for decades. The introduction of locks, weirs and barrages (Figure 1) in the early part of the 20th Century to contain water flow has resulted in extensive agricultural development. However, the permanent inundation of the river, wetland and lake and systems has had a significant impact on the formation of soils in these ecosystems because of loss of natural wetting-drying cycles so important to biodiversity and wetland functioning. T his change has promoted the build-up of sulfide minerals (mostly iron pyrite) and sulfidic materials in these subaqueous soils.

However, prolonged extreme drought conditions in large parts of the MDB system (Figure 1) have caused water levels to recede in the river and wetland systems (including the freshwater Lower Lakes: Albert and Alexandrina), which has begun to dry up, uncovering extensive areas of sulfidic material in the subaqueous soils, which are much more abundant than previously assumed. With drainage, sulfidic material in the anaerobic soils become oxidised and transform to sulfuric material (pH <4), with consequent water quality, ecological and pu blic health issues from metal/metalloid mobilization, de-oxygenation, noxious gas release and wind erosion. These effects have been particularly severe in the Lower Murray and Lower Lakes region of South Australia where research has progressed beyond studying the occurrence of acid sulfate soils to understanding the impacts on adjacent environments through the mobilization/transport of acidity and solutes (e.g. Fitzpatrick et al. 2008a,b). Such questions have involved harnessing skills in aqueous geochemistry, hydrodynamic modelling and ecological risk assessment. These investigations have elevated investigations into the occurrence and impacts of inland acid sulfate soils across the entire MDB (Fitzpatrick and Shand 2008).

Previous studies by CSIRO Land a nd Water developed a generalised conceptual model to explain four sequential drying phases and the development of different ASS Subtypes that occur: deep water sulfidic ASS → subaqueous ASS → waterlogged and saturated ASS → drained and unsaturated ASS (Fitzpatrick et al. 2008a,b). B y applying this model, Fitzpatrick et al. (2008a,b) integrated locally detailed field survey and laboratory data and used the Australian Soil Classification (Isbell 1996) to derive fourteen subtypes of ASS conforming to the map legend of the Atlas of Australian ASS.
A series of conceptual process models for each of the lakes (Alexandrina and Albert) and lower River Murray systems were applied to:

- explain the sequential formation and transformation of sulfidic material to sulfuric material in various subtypes of ASS (5,500 BC to the extreme drought conditions of 2006-2008),
- explain and predict new occurrences of minerals, their formation and transformation (e.g. pyrite to sideronatrite to schwertmannite; pyrite to natrojarosite),
- predict the impacts of further drought on ASS formation and decline in water quality, and
- develop remediation and management options for specific ASS environments.

Combined bathymetry, soil and vegetation mapping in GIS was used to help predict the distribution of the various subtypes of ASS according to three predictive scenario maps (Fitzpatrick et al. 2008a,b), which depict sequential changes in ASS materials at different water levels in Lake Alexandrina of +0.5 m AHD (pre-drought), -0.5 m (approximate level during early 2008), and for -1.5 m AHD (an extreme case, should lower lake inflows persist).

Soil management based on soil type and natural processes: Pictorial manuals for land management planning

The sequence of steps used to develop easy-to-follow pictorial manuals for identifying soil indicators, land use options and best management practices are shown in Figure 3. Steps 1-5 describe soil layers and construct them in toposequences (descriptive, explanatory or predictive models), which are used to help map soil types in areas with variable geochemistry (Fitzpatrick et al 2003a,b).

Steps 6-9 involve local communities in developing the manual by integration and a doption, where knowledge of the hydrological and soil-regolith processes models (bottom half of Figure 2) and production systems are bought together in recommendations for appropriate best management practices (top half of Figure 2). For example, in the Mount Lofty Ranges in South Australia (Fitzpatrick et al. 1997; 2003) and Woorndoo region in Victoria (Figure 3; Fitzpatrick et al. 1997; 2003; Cox et al. 1999) fencing protected saline-sulfidic wetlands from physical disturbance (i.e. cattle) has:

- Facilitated the reestablishment of more reducing soil conditions in the A horizon.
- Decreased the amount of pyrite oxidation.
- Allowed rapid recovery of wetland vegetation.
- Prevented physical erosion of the A horizon.
- Allowed a return to neutral pH (pH = 6.5 to 7).

Finally, we present as part of the conceptual models best management principles and a summary of management options for the main subtypes of ASS encountered in this region. For example, refilling of Lake Albert with water from Lake Alexandrina to maintain levels at-0.6 m AHD, below which modelling suggests acidification will occur.

CONCLUSIONS

Current extreme drought conditions, long-term climate shifts and rising energy prices will place increasing pressures on existing water resource, land use and soil management practices, probably making sustainable soil management more difficult in many regions around the world, such as in the MDB. The crisis of declining soil and water quality or productivity in the MDB is also the result of dysfunctional land and water management systems but made worse by drought impacts and responses. Over the past 18 months or so there has been a marked 'demand pull' for ASS information in the MDB at a high level of policy and decision-making.

There are numerous ways in which agriculture can contribute to improving soil and water quality. For example, by closely linking agriculture to land management based on saline and ASS types via soil-water toposequence models. Although some ASS models, risk maps and options of best management principles have been developed for some areas in Australia, large gaps remain from a national perspective. The fate and effects of heavy metals, metalloids and non-metals, which are mobilised when ASS materials (sulfidic, sulfuric and monosulfidic) are disturbed, remains poorly understood. Their interaction with organic and inorganic colloids, transformations following sedimentary burial and fluxes to the water column are largely unknown. The response of disturbed systems to different management options is poorly tested and understood.

The services provided by soils to improve water quality and the resilience and profitability of farming systems are irreplaceable and invaluable! Importantly, if agriculture technologies are directed at improving soil and water quality, a more holistic perspective must be adopted to ensure that agricultural intervention will be sustainable for whole landscapes and adopted by farmers and communities. Hence, now, more than ever before, we need to be managing soil resources wisely.

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Indian Model For Food Security

Microirrigation For Small & Marginal Farmers … A New initiative to Alleviate Hunger and Poverty:

A Success Story

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Contents

Indian Agriculture Scenario

Strengths

- Rich Bio-diversity
- Arable land
- Climate
- Strong and well dispersed research and extension system

Opportunities

- Bridgeable yield crops
- Exports
- Agro-based Industry
- Horticulture
- Untapped potential in the N.E.

Weakness

- Fragmentation of land
- Low Technology Inputs
- Unsustainable Water Management
- Poor Infrastructure
- Low value addition

Threats

- Unsustainable Resource Use
- Unsustainable Regional Development
- Imports

Basic Features of the Indian Economy

- Agriculture plays an important, though declining role in the economy (46% in 1970s to 17.5% in 2006)
- Agriculture provides 57% of India's total employment and 73% of India's total rural employment
- Small / marginal farms owning or operating less than 2 ha land – 84% (38% in 1953-54)
- Share of small & marginal farmers in total crop output is 54%
- Only 25% of the irrigated area in case of small & marginal farmers is from canals
- Nearly 49% of Indian farmers are under debt (Andhra Pradesh – 82% indebted, Tamilnadu – 75% & Punjab 65%)
- 84% of farmer housholds spend (US$ 55.4/month) more than they earn (US$ 42.3/month)
- Nearly 77% of India's population lives on less than ½ US$/day
- Around 26 percent of India's population lives below the poverty line (US$ 1.25/day)

Basic Features of the Indian Economy

- Only 24 per cent of the sub-marginal farmers and 29 per cent of the marginal farmers replaced seeds every year, compared to 40 per cent of the large farmers
- Nearly 60 per cent of the farmer households in India are not able to access any source of information on modern technology (main sources: 16.7% Progressive farmers, 13.1% input dealers, 13% radio & 5.7% Extension officers)
- Insurance is an uncommon practice with only 4 per cent farmers having ever insured their crop.
- Almost 46 per cent of Indian children under the age of 3 suffer from malnutrition
- Agriculture is getting feminished (73% women as compared to 52% men)

Source: Report of the National Commission for Enterprises in the Unorganised sector (August 2007)

Water, Irrigation and Poverty

1. Agriculture made significant contribution to economic growth. Its value increased 3.2 times in real terms in 50 years
2. Irrigated agriculture sector has been fundamental to India's economic development and poverty alleviation.
3. Irrigation largest absorber of rural labour force
4. Growth in grain production negatively impacts rural poverty
5. Stagnation in net cropped area and area under food grains
6. Irrigation key to sustaining agriculture growth, and ensuring food security at the national, regional and domestic level
7. India's diversion of water for irrigation is largest in the world—569 m^3/capita

Commodity	Rank India	World Rank 2005	Production Avg 2003-2005	
			Billion $	Million T
Paddy rice	1	2	27.5	129.2
Buffalo milk	2	1	25.2	50.5
Wheat	3	2	10.9	69.7
Cow milk	4	2	10.0	37.5
Fresh vegetables	5	2	6.6	34.9
Sugar cane	6	2	5.2	250.0
Potatoes	7	3	3.6	25.0
Groundnuts	8	2	3.4	7.1
Pimento	9	1	3.3	1.1
Buffalo meat	10	9	3.1	1.5

Yield increase through irrigation contributed more to growth in grain production than growth in Cropped area

Microirrigation For Small & Marginal Farmers … A New initiative to Alleviate Hunger and Poverty

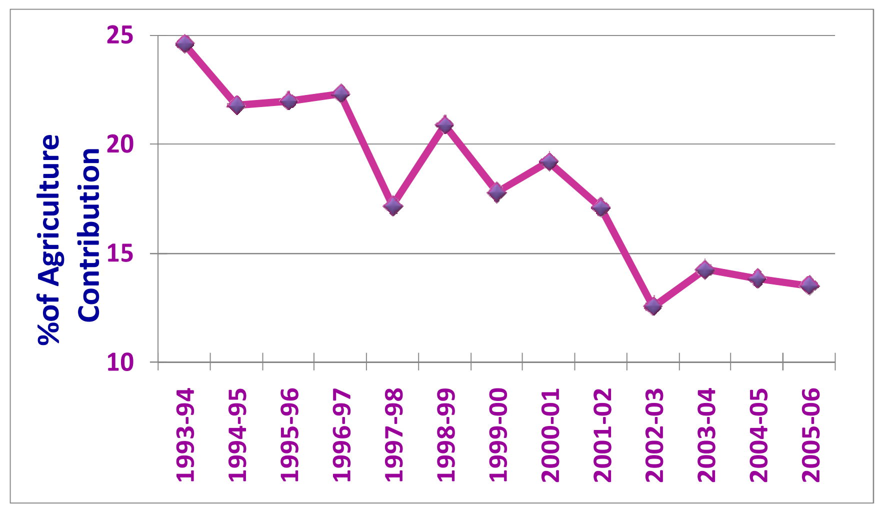
Access to irrigation water, or the means to use the water they have more productively, is a key to increasing their crop production, their incomes, & their household food security.

Combating persistent rural hunger and poverty in a world of increasing water scarcity requires new approaches to agricultural and economic development.

Millions of poor farm families lack access to irrigation water and/or to the technologies to use what limited water they have efficiently and productively.

Land & Water Statistics	
Geographical area	27.5 m ha
Gross cropped area	13.362 m ha
Net cropped area	10.745 m ha
Gross irrigated area	6.069 m ha
Net irrigated area	4.452 m ha
Fertility index	1.45 N (Low), 1.97 P (Medium), 2.52 K (High)
NPK use	185.9 kg/ha
Per capita Food grain availability	160.4 kg/year

Geographical location of APMIP



Agriculture contribution to GDP

Description of the Kuppam Project area

1. Semiarid climate
2. Low (540 mm/year) & erratic rainfall
3. Chronically drought prone area
4. Land capability class – III
5. Undulated terrain
6. Small & Marginal farmers (77%)
7. Population below poverty line – 50%
8. Cropping intensity – 100%
9. Soil type – Alfisols, crust prone with shallow depth (40 – 60 cm)
10. Poor fertility status (fertility index) & Low CEC
11. Fertilizer use – 81 kg/ha
12. Low water holding capacity (60 – 80 mm/m depth)

Goal And Approach

"Growing of High Value Crops with Right Tools & Agronomic Services to exploit the Embodied Agriculture Potential from the local resources by establishing a Sustainable Agricultural Production system to harvest better quality agri-produce to meet both domestic & international standards and to Realize Higher Farm Profits"

Kuppam Pilot Project

Summary of Benefits to the Farmer

1. Greater return on investment in agriculture (Profitable enterprise)
2. Saving in water, energy, fertilizer and labour requirement (< Expenses)
3. Improved pest and disease control (< Expenses)
4. Enhanced yield and premium quality (= Increased income)
5. Use of marginal quality (saline) waters successfully (> Water)
6. Free movement of farm equipment & machinery (Management flexibility)
7. Use of wastelands for arable crop production (Increased area & value)
8. Modernization of agriculture (> GDP)
9. Maintenance of soil quality & Environmental friendly (Sustainability)

APMIP – Vision

1. Poverty alleviation
2. Productive agriculture
3. Farm profitability
4. Food & Ecological security
5. Employment generation
6. Human resource development
7. Higher energy efficiency in agriculture sector
8. Reducing cost of production
9. Preserving the social fabric of rural communities

Training &Capacity building through Agronomic & Technical Support services

1. Training
   a) Class room – Theoretical Concepts & Principles
   b) On-field – Practical skills
   c) Field visits by experts
2. Method demonstrations – Fertigation, Planting, Pruning …….
3. Result demonstrations – Germination irrigation, Acid treatment …
4. Study tours
5. Participatory meetings with input suppliers viz., seeds, fertilizers, pesticide and financing institutions
6. Arranging seminars by Local Agronomists, Crop & Product Experts
7. Crop campaigns and Expert Crop Teams
8. Liaison with progressive growers & Consultants
9. Publications – Crop growing manuals, Basic crop sheets, NESSS, Success stories, Power Point Presentations etc

Uniqueness of APMIP

1. Use of only BIS certified products
2. Standardization of Drip and Sprinkler irrigation system modules
3. Uniform price fixation of irrigation systems / products
4. Highest & Uniform subsidy pattern to all categories of farmers
5. Agronomic services to farmers for 2 years by MI companies
6. Operation & Maintenance by MI Companies for 5 years
7. Training and capacity building of farmers and stakeholders
8. Stringent penalties for violation of quality control & assurance
9. Performance bank guarantee by MI Supplier
10. Independent Monitoring & Evaluation by external agencies
11. Applicable to all categories (ST, SC, BC, OC, SF, MF) of farmers
12. Eligibility criteria - Farmers should have water & power source
13. Quality control by CIPET , Hyderabad

Special benefits by Government & Banks

1. Exemption of Sales Tax (4%) on all MI system
2. Insurance coverage for MI systems at lower premium rate of 0.25% of system cost
3. Low bank interest rates: 9% to small and marginal farmers & 10% to other farmers
4. Waiver of stamp duty on all documents while taking loans by farmers
5. Relaxation of collateral security norms up to Rs.50, 000/- loan for Loanee farmers

Monitoring and evaluation

Three agencies

1. Engineering Staff College of India (Telangana Districts)
2. CRIDA (Rayalaseema Districts)
3. Agricultural Finance Corporation (Coastal Andhra Districts)

Evaluation parameters

i) Bench Mark survey report,
ii) Design of the system,
iii) Supply of MI equipment as per final invoice,
iv) Installation,
v) Operation and maintenance,
vi) Agronomic and extension services
vii) Quality control

Sample size: 10% of MI systems

Summary of APMIP Project Benefits (in Figures) (State of Andhra Pradesh – India) (*)

1. Number of Farmers in the Project: 187,000 (March 2008)
2. Total area covered: 376,294 hectares (Up to March 2008)
   - Drip 236,754
   - Sprinklers 139,540
3. Crops:

   Fruits (Papaya, Sweet orange, Acid lime, Mango, Pomegranate etc),

   Vegetables (Tomato, Egg plant, Bell Pepper, Gourds, Beans etc),

   Spices: Chili, Ginger & Turmeric etc

   Field crops: Mulberry, Cotton, Sugarcane, Potatoes
4. Cost of Microirrigation Systems:

   Total investment: US$ 230.7 million

   Government Subsidy: US$ 141.9 million

   Farmers' Contribution: US$ 88.8 million

Summary of APMIP Project Benefits (in Figures) (State of Andhra Pradesh – India) (*)

5. Annual cost (CRF 0.2055) based on
   Total cost: US$ 54 million
   Farmers contribution: US$ 19 million
6. Additional Yield: @ US$ 300/ha minimum = US$ 130.2 million
7. Payback period:
   - For total cost: 2 years
   - For Farmers' contribution: 0.7 years
8. R.O.I. on Total Cost: 240%
9. R.O.I. on Farmers' share: 690%
10. Water saved (est.): 1890 million m^3
11. Power saved: 188 million kwh

(*) Data supplied by APMIP Cell-Government of Andhra Pradesh

AN UPDATE ON CLIMATE CHANGE PROJECTIONS AND ITS INFLUENCE IN FOOD SECURITY IN SOUTHERN AFRICA

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During the ongoing debate about climate change, new future projections of change due to anthropogenic and other influences are being generated on a frequent basis, mostly by reports from the Inter-Governmental Panel on Climate Change (IPCC)[1]. Although the IPCC (2007) report agrees on projections of increasing temperature over southern Africa, model simulations generally do not project a significant deviation in annual rainfall totals over the next 100 years. This is confirmed by observations where no strong trends in annual rainfall totals could yet be identified. Observations, however, show signals of possible shift in season, with less rain observed over the summer rainfall region during the late summer (April and May), and more rain observed over the western parts of southern Africa during the late winter (July and September).

A number of projects, some independent from each other, have been implemented or completed over recent years to address the impact of climate variability and change on agriculture and food security over southern Africa (Kurukulasuriya and Mendelsohn, 2007; Mendelsohn *et al*., 2001). Some reports from these projects, especially those from the World Bank[2], have expressed deep concern about what the future might hold for African communities under conditions of changing climate variability or longer term greenhouse warming (see for example Seo and Mendelsohn, 2007). These concerns have emphasised the need for more drastic action to determine vulnerability through risk assessment, and to facilitate decision making and even early warning systems (EWSs). The benefit of research conducted over recent years, is that it has established a good basis to understand the integrated nature of the agricultural sectors and its vulnerability to changes in climate. In many cases, it has also established networks between African scientists and the international community.

This talk will give an overview about our latest knowledge on climate change projections over southern Africa, and according to this, will evaluate findings in the most recent reports of the World Bank.

References:

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[1] www.ipcc.ch
[2] http://www.worldbank.org (click on “data and research)