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### IRRIGATION IN SOUTHERN AFRICA: AN ANNOTATED BIBLIOGRAPHY

by

Amalia Rinaldi

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Department of Agricultural Economics  
Michigan State University  
East Lansing, Michigan 48824-1039

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## PREFACE

One of the important goals of the Southern African Development Coordination Conference is to increase food security for both rural and urban people through a broad range of activities, including the expansion of irrigated agriculture. Little is known, however, about recently completed and on-going research on irrigation in the region.

The purpose of this bibliography is to assess the existing literature on irrigation and food security as the first step in the preparation of a research agenda for the 1980s and 1990s. We hope that this paper will stimulate an exchange of information about irrigation research in Africa.

## ACKNOWLEDGMENTS

There are many people who have assisted in the preparation of this bibliography. I would like to give special thanks to Eugene de Benko, Learthern Dorsey, Onuma Ezera and Pauline Sondag (Michigan State University); Hans E. Panofsky, Maidel Cason, and Daniel Britts (Northwestern University); Peter Ballantine (World Bank); Anne Salda, (World Bank/IMF Joint Library); Anne Zelder, (African and Middle Eastern Division of Research Services, Library of Congress); Antony Hall and Glen H. Cannell (University of California, Riverside); N. Gene Wright (Office of Arid Lands Studies, the University of Arizona).

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## ACRONYMS USED IN TEXT AND REFERENCES

- CDC - Commonwealth Development Corporation,
- FAO - Food and Agriculture Organization of the United Nations,
- IBRD - International Bank for Reconstruction and Development (World Bank),
- IFAD - International Fund for Agricultural Development,
- OECD - Organization for Economic Cooperation and Development,
- SADCC - Southern African Development Coordination Conference,
- UNCTAD - United Nations Conference on Trade and Development
- UNDP - United Nations Development Program,
- UNDP-SF - United Nations Development Program, Special Fund,
- USAID - United States Agency for International Development,
- USDA - United States Department of Agriculture,
- UNESCO - United Nations Educational, Scientific, Cultural Organization.

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## INTRODUCTION

Irrigation can increase agricultural output and food security in Africa. However, the experience to date with irrigation in Africa is sobering. Costs are frequently underestimated and yields are usually overestimated in feasibility studies. Moreover, it has been difficult for African states to develop irrigation systems operated and maintained by farmers. SADCC states are keenly interested in irrigation as a means of reducing the dependency on rainfall and increasing food security at the farm level, but they lack information about recently completed and current research on irrigation in the region.

The purpose of this bibliography is to identify available information on the socio-economic and institutional aspects of irrigated agriculture in the nine SADCC countries in Southern Africa: Angola, Botswana, Lesotho, Malawi, Mozambique, Swaziland, Tanzania, Zambia, and Zimbabwe. We have also included a few references from the Republic of South Africa. The material abstracted was written or published almost exclusively during the period 1970-1984.

This bibliography is intended for use by researchers, teachers, government officials, and rural development personnel working in Southern Africa. Although it is comprehensive in scope, it is not intended to be a complete compilation of all references on the subject. It was compiled from sources in North America, Europe and Zimbabwe.

Most of the literature on Angola and Mozambique is in Portuguese. The literature on South Africa is in Afrikaans, English, and German. The remaining sources are in English. English abstracts are provided for each item.

The following abstracts, major bibliographic sources, and library catalogues have been consulted in the preparation of this bibliography.

### A. Abstracts

Rural Sociology Abstracts, World Agricultural Economics, Agricultural Engineering Abstracts, Arid Lands Abstracts, Rural Development Abstracts, Soils and Fertilizers, Social Science Citation Index, Waterlit (South African Water Information Centre), Zambia Science Abstracts, Select Water Research Abstracts, Current Annotated Bibliography of Irrigation (IRRICAB), Southern Africa Development Information Documentation Exchange, United Nations Food and Agriculture Organization Documentation Current Bibliography, Dissertation Abstracts International (Volumes 31-43), Index of South African Publications (1970-1983).

### B. Bibliographies

Bolder, R.B., ed. Malawi. World Bibliographic Series. Vol. 18. Oxford: Clio Press, 1979.

African Bibliographic Center. A Current Bibliography of African Affairs. Volumes 3-16. New York: Baywood.

Lawami, S.M., et al. Farming Systems in Africa, A Working Bibliography, 1930-78. Boston: G.K. Hall Co, 1979.

Lenwood, G. Davis. Irrigation and Water Systems in Africa: An Introductory Survey. Monticello: Council of Planning Librarian Exchange Bibliography 1206.

Pollack, O.B. and Pollack, K. Rhodesia/Zimbabwe An International Bibliography. Boston: G.K. Hall and Co., 1979.

Great Britain. Ministry of Overseas Development, Land Resource Division. Zambia: Land Resource Bibliography. Tolworth Tower, England, 1977.

Willet, Shelagh M. and Ambrose, David P. Lesotho, A Comprehensive Bibliography. Santa Barbara, California: Clio Press, 1980.

### C. Libraries

Selected material from the following libraries:

- Library of Congress, African and Middle Eastern Division of Research Services, Washington.
- University of Arizona, Office of Arid Land Studies, Tucson.
- Michigan State University, Sahel Documentation Center, East Lansing.
- University of California, Riverside.
- University of California, Los Angeles, Water Resource Archives.
- Northwestern University, Melville J. Herskovits Library of African Studies, Evanston.
- World Bank/IMF, Joint Library, Washington.
- University of Zimbabwe, Harare, Zimbabwe.

## AFRICA GENERAL

Abernethy, C.L. "Methodology for Studies of Irrigation Water Management." In African Regional Symposium on Small-Holder Irrigation, pp. 1-8. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

The author discusses research on irrigation management in developing countries during the last decade from the viewpoint of a research engineer. He argues that irrigation management should be measured by: a productivity measure (kg/square meters or t/ha) and an equity measure (e.g., coefficient of variation of water supply). The parameters to be considered in the analysis include: 1) hydraulic and civil engineering parameters, 2) agricultural parameters, 3) socio-economic parameters. Recommends a step-by-step approach to identify the influence of such parameters and possibly subdivide the problems and advance partial solutions.

Balarin, John D. "Fish Farming and Irrigation: Integrated Techniques for Protein Production." In African Regional Symposium on Small-Holder Irrigation, pp. 151-165. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

Discusses the advantages of incorporating fish culture projects into irrigation schemes in Africa and in particular in Zimbabwe. The advantages of fish farming are: 1) aquaculture produces effluents that can fertilize crops; 2) crop waste provides a supplemental food source; 3) fish can assist in weeding channels and paddies; 4) water-borne diseases are likely to be controlled.

Barnett, Tony. "Small-Scale Irrigation in Sub-Saharan Africa: Sparse Lessons, Big Problems, Any Solutions?" Public Administration and Development 4(1984):21-47.

From a review of irrigation schemes, the author identifies the major social and administrative problems confronting those working to improve and extend small-scale irrigation in Africa. Six general issues are identified and discussed: 1) the relation between the direct producer's benefit and wider social benefits; 2) problems of control; 3) commitment to hierarchy; 4) production units at work; 5) how to learn from farmers' use of water; 6) how to plan for changes that will occur after irrigation is introduced.

Batchelor, C.H. "Drip Irrigation for Small Holders." In African Regional Symposium on Small-Holder Irrigation, pp. 115-122. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

The author, who is with the Institute of Hydrology of Wallingford, England, discusses the success of drip irrigation in many countries during the last fifteen years. He notes that before systems are purchased, careful attention should be given to local crops and agronomic practices, economics, and extension services.

Blackie, M.J., ed. African Regional Symposium on Small-Holder Irrigation. Harare: University of Zimbabwe, Department of Land Management, 1984.

Thirty-nine papers presented in September 1984 at a symposium organized by the Overseas Development Unit of Hydraulics Research, Wallingford, in collaboration with the University of Zimbabwe. The symposium brought together engineers, agriculturalists, scientists, researchers, and planners to analyze small-holder irrigation in Africa. Six papers provide an overview of major issues. They are followed by thirty-three technical papers on specific questions related to the design, rehabilitation, management, and evaluation of small-holder irrigation schemes. The papers were based on research in twelve African and two Asian countries.

Carruthers, Ian D., ed. Aid for the Development of Irrigation. Paris: OECD, 1984.

Presents the results of an informal workshop on aid-financed irrigation projects. Includes some of the papers presented at the meeting and additional chapters drawing on the discussion. Based on an issues paper prepared by Ian Carruthers from Wye College.

Eicher, Carl K. and Baker, Doyle C. Research on Agricultural Development in Sub-Saharan Africa: A Critical Survey. East Lansing, Michigan State University, International Development Paper No. 1, 1982, pp. 133-139.

After reviewing the important literature on irrigation over the 1970-1982 period, the authors conclude that although research on the economics of irrigation is fragmentary, there is strong support for small-scale irrigation strategies in Africa in the 1980s and 1990s. Priority should be given to increasing flood-recession farming, ground-water development with small pumps, land reclamation through drainage and water control, and an increase in small perimeters that are developed and maintained by family labor. Second priority should be given to improving the performance of existing large perimeters and river basin complexes.

Hilton, D.J. "The Role of Wind-Powered Pumps in Water Supply and Small-Scale Irrigation in East Africa." In The Role of Water Resources in Development. Proceedings of the 13th Annual Symposium of the East African Academy, pp. 232-240. Edited by John B. Castelino and Canute P.M. Khamala. Nairobi: National Academy for the Advancement of the Arts and Sciences, 1974.

General assessment of the potential for utilizing East Africa's wind resources for pumping water. While very few areas receive winds that are both strong and reliable, numerous areas have medium potential for pumping water. In many areas, the wind tends to be strongest during the dry season, when the most water is required. The costs of systems using locally made wind pumps are compared with those using imported diesel pump units.

Jewsbury, J.M. "Small-Scale Irrigation Projects and their Implications for Health." In African Regional Symposium on Small-Holder Irrigation, pp. 41-56. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

Describes some of the potential adverse effects small-scale irrigation projects have on health. Although experience has shown that small-scale schemes may be a comparatively greater risk to health than larger projects, much can be done to prevent such problems from arising if planners give them due consideration.

Makadho, Johannes M. "A Review of Some Factors Affecting the Viability of Small-Holder Irrigation Schemes in Africa." In African Regional Symposium on Small-Holder Irrigation, pp. 209-219. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

Discusses some of the factors that lead to the failure of small-holder irrigation projects: 1) diminishing returns, 2) declining yields per unit area, 3) lack of interest by the farmers, 4) continual indebtedness. Such failures are usually attributed directly to the farmers, yet the problem often stems from an overall lack of viability in the project design. Failures may be minimized by designing projects that place irrigation activities in the hands of the farmer. Farmer participation can provide an important basis for project planning and design.

Rydzewski, Janusz R. "Appraisal Techniques for Small-Scale Irrigation Development." In African Regional Symposium on Small-Holder Irrigation, pp. 25-40. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

The author, director of the Institute of Irrigation Studies, University of Southampton, UK, discusses the methodology of social cost-benefit analysis and its relevance to small-scale irrigated agriculture. Highlights the viewpoints of the entrepreneur, the project manager, and the national planner. Describes the dilemma caused by market imperfections and various methodologies that deal with it. Stresses the role of the sociologist in forecasting the future behavior of a rural community: "it is of little use to make projections of the costs and benefits of a project without making a conscious effort to ensure that such projections, especially on the benefit side, have a chance of becoming facts." Concludes by stressing the need for the planner/designer to prepare an unbiased decision matrix which can serve as a basis for the final project selection under a wide variety of social systems.

Singh, Jaswant. "Selection and Operation of Centrifugal Pumps for Small-Holder Irrigation." In African Regional Symposium on Small-Holder Irrigation, pp. 181-189. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

The author, an engineer with the National Sugar Research Station of Kenya, discusses the need for drainage and irrigation projects that will stabilize and maximize sugar cane production in Kenya. Discusses the selection of centrifugal pumps for small holdings.

Tiffen, Mary. "Human Resources in African Irrigation." In African Regional Symposium on Small-Holder Irrigation, pp. 57-73. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

Discusses the characteristics and the performance of a number of 1) farmer-initiated schemes, 2) irrigation systems stimulated by outside intervention, 3) government imposed systems in Nigeria, Western Africa, Sudan, Kenya, Zambia and Swaziland. Argues that "farmers and motivated managers are as essential for irrigation as suitable land and water resources."

Underhill, H.W. "The Roles of Governmental and Non-Governmental Organizations and International Agencies in Small-Holder Irrigation Development." In African Regional Symposium on Small-Holder Irrigation, pp. 9-23. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

The author, an official with the FAO, argues that experience has shown that the self-reliance and motivation on which bottom-up development is based can easily be undermined by a paternalistic approach. Stresses the role that national governments (assisted by local and national non-government organizations, bilateral aid, and technical assistance to governmental extension and small-scale irrigation services) have to play in developing a "positive environment" in which the farmers may take responsibility for their own development.

United Nations, Food and Agriculture Organization. International Directory of Agricultural Engineering Institutions, 1983.

Updates the 1973 edition of the International Directory of Agricultural Engineering Institutions. Includes names and addresses of international and national institutions dealing with land and water development. The Directory is organized by country, in alphabetical order, and provides detailed information on scientific staff, training, and research in each agency.

## ANGOLA

Almeida, A.R.P. de. "Bases for the Agricultural Planning of the Bengo Valley." Reordenamento 40(1975):40-48.

Discusses: 1) the agricultural calendar for cotton, sunflowers, bananas, and mangoes; 2) monthly irrigation schedules for the first three crops; 3) field layout to reduce erosion; 4) the area under the four crops.

Diniz, A.C. and Angular, F.Q. de B. Resources of Irrigable Land in the Cubango Basin. Nova Lisboa: Instituto de Investigacao Agronomica de Angola, Serie Technica, No. 33, 1973.

This study is part of an appraisal of the water resources of Angola for agriculture. The Cubango Basin is divided into: 1) the Northern region, which is suited for dryland farming; and 2) the Southern region, where agriculture is limited by shortage and poor distribution of rainfall. Areas along the river are suitable for irrigation. Seven geomorphological units of the lower Cubango were identified following photo-interpretation and field surveys; each unit is described in terms of climate, geology, morphology, vegetation and soils and its suitability for irrigation.

Moreno, B.F. "O Plano do Cunene - Desafio ao Futuro de Angola" (The Cunene Scheme - A Challenge to the Future of Angola). Fomento 12(1)(1974):3-12.

The Cunene Scheme started as a pilot irrigation study but has developed into a regional development plan. The scheme includes the Gove Dam and a settlement scheme for 10,000 people in the Quiteva-Humbe zone. Discusses agronomic and cattle management experiments being carried out.

Portas, C.A., Araujo, J.A. and Fernandes, A.R. Notes on Olive Plantings in Mocamedes. Nova Lisboa: Instituto de Investigacao Agronomica de Angola, Serie Technica, No. 39, 1974.

A report on regional olive production. The area now planted in olives is about 50 ha, but the potential is several thousand ha on irrigated alluvial land.

Soares, A. de S. "Improvement of Agricultural Potential in the Plateau of Angola." Formento 12(2)(1974):283-296.

Discusses the agricultural potential and the irrigation works required in the plateau of Angola.

## B O T S W A N A

Eicher, Fischer Shirley. Rural Development in Botswana, A Selected Bibliography, 1966-1980. Washington, D.C.: African Bibliographic Center, 1981.

This extensive bibliography is intended as an aid to researchers, teachers, government officials and rural development personnel. It is organized around 17 categories, including a section on geography, natural resources, and ecology.

Faaland, J. Report of the Special Programming Mission to Botswana. Rome: IFAD, 1979.

The author, leader of the 1978 IFAD mission to Botswana, summarizes an IFAD report focusing on improving 1) domestic food production and 2) the level and quality of nutrition in the country. Describes the four national rural development programs--the Arable Land Development Program (ALDEP), the Small Holder Land Preparation Program (SLAPP), the Remote Dwellers Development Program (RADDEP), and the Melapo Development Program (MELDEP). One of the programs, MELDEP, was introduced to extend cultivated land in Ngamiland by controlled flood irrigation. Advocates a flexible approach to all four programs.

Great Britain. Ministry of Overseas Development, Land Resources Division. The Irrigation Potential of Soils Along the Main Rivers of Eastern Botswana - A Reconnaissance Assessment, by A.J.B. Mitchell. Land Resource Study 7, 1976.

Study of areas suitable for irrigation. Describes the climatic, soil, and water requirements of crops suitable for irrigation. Argues that, from an economic point of view, only 11 percent of this area has potential for development of irrigation schemes in the foreseeable future because of water shortages and water storage costs. Selects 17 areas which have irrigation potential.

Roe, Emery. Development of Livestock, Agriculture and Water Supplies in Botswana Before Independence: A Short History and Policy Analysis. Ithaca, N.Y.: Cornell University, Center for International Studies, Occasional Paper No. 10, 1980.

Description and discussion of the major factors that contributed to the livestock sector's prevalence over the crop sector from 1895 to 1965. The author argues that investments in livestock have been enhanced by a substantially greater allocation of research, innovation, and funding. Major problems facing the agricultural sector are examined: 1) water security, 2) labor shortages, 3) a lack of high-yield/drought-resistant grains with low cultivation harvesting requirements, 4) lack of economic incentives for sustained production.



Stevenson, Alex. "Agriculture, Water and Environment in Botswana." Natural Resources Forum 2(1977):53-62.

Advocates inter-disciplinary approaches to understanding the changing relationships between man, land and water.

Thompson, Keith. "The Okavango Delta and its Future Utilization: An Attempt at and a Synthesis of the Proceedings." In Symposium on the Okavango Delta, August 30th-September 2nd, 1976, pp. 3-12. Gaborone: Botswana Society, 1976.

The Symposium reviewed almost 10 years of research, covering the ecology, hydrology, topography, and human resources of the Delta. The author argues that there is not enough data to predict the full effects of irrigation projects over the long-term. Main obstacles to overcome are: 1) complexity of the natural system (need to utilize resources suitable for human development without subverting natural balance that assures consistency of such resources), 2) poor soil characteristics, 3) lack of infrastructures that would make intensive agriculture profitable.

United Nations. Food and Agriculture Organization. Botswana--Survey and Training for Development of Water Resources and Agricultural Production: Final Report of Irrigation Agronomist by Said Sherif Walid, 1970.

Discusses the results of 1970 agronomical trials of irrigation at Vakwe, Mahalapye, and the Shashi area. Estimates irrigation requirements and fertilizer yields in various soils and argues that 1) possibilities for irrigation in the Mahalapye are limited, 2) sprinkler irrigation for maize, cotton, wheat, and vegetable production is well suited to the Shashi River and Mogobane areas.

\_\_\_\_\_. Food and Agriculture Organization. Soil and Irrigation Potential of the Mahalapye and Mogobane Pilot Schemes, by W. Siderius. Botswana--Surveys and Training for the Development of Water Resources and Agricultural Production. Technical Note No. 16, 1971.

This report presents the findings of a detailed soil survey of an area five miles down-stream from Mahalapye on the west bank of the Mahalapye River. A combined irrigation and dryland agricultural demonstration plot was examined. Recommends the application of N, P, K fertilizer for sustained high yields. Concludes that there may not be enough water to irrigate the entire plot during the dry winter months and during years of low summer rainfall.

\_\_\_\_\_. Food and Agriculture Organization. The Mahalapshire Catchment Model, by I.M. Goodwill. Botswana--Surveys and Training for the Development of Water Resources and Agricultural Production. Technical Note No. 29, 1972.

A mathematical catchment model for the Mahalapshire River catchment in Eastern Botswana. Argues that there is insufficient data to calibrate the model accurately. Recommends concentration on the collection of high quality data, especially streamflow data.

\_\_\_\_\_. Food and Agriculture Organization. Investigation on Soil at Motopi and Moshu, Botswana, by B. Braun. Technical Note No. 1, 1975.

Presents the results of field trials of cash crops carried out at the research stations at Motopi and Moshu in 1974. In Motopi, plants grow under sprinkler irrigation. Analyzes the soil's physical and chemical characteristics and argues that these, not uneven cultivation conditions, are the main causes of uneven plant growth in Ngamiland.

United Nations Development Program. Rainfall and Evaporation in Botswana, by J.G. Pike. Technical Document No. 1, 1971.

Provides data on rainfall distribution and variation. Estimates long-term trends. Examines the evaporation and availability of water, the measurement and estimation of evaporation, and the use of the Penman method of calculation as well as an evaporation formula prepared for Botswana.

Upton, Martin. Irrigation in Botswana. Reading: University of Reading, Department of Agricultural Economics, Development Study No. 5, 1969.

Argues that with the existing pattern of climate and of agriculture in Botswana there is an opportunity for increasing crop yields by irrigation. Discusses preliminary cost studies of various water services, the linear programming method of estimating crop water requirements, and the planning of systems of irrigated agriculture as well as returns for individual yield crops and intensive vegetable production. A chapter reports on social cost-benefit analysis of irrigation projects. Considers specific schemes: 1) publicly financed irrigation schemes (The Nxaragha Valley Settlement, the president's irrigation scheme at Chadibe, the Tuli Block Pump Schemes, the Mogobane, Tlokweg Irrigation Schemes, irrigation from the Shashi, and the Ramaquabane rivers); 2) private irrigation schemes (on the Thamalakane River, in Serowe); 3) experimental schemes. Compares irrigation with other forms of investment (cattle production, dryland mixed farming). Strongly recommends that consideration be given to technical problems. Concludes by arguing that the place of irrigation in the development of Botswana is likely to be limited.

Whiteman, P.T.S. "Moisture Conservation by Fallowing in Botswana." Experimental Agriculture 11(1975):305-314.

Report of an experiment to assess the effect of summer fallow on sorghum yields. Discusses the advantages of summer fallow and argues that its adoption will depend upon an extension program that promotes summer fallow as the central point of a whole system of land use.

Wiles, G.C. "Planning for Small-Scale Irrigated Vegetable Production in Botswana." In African Regional Symposium on Small-Holder Irrigation, pp. 193-200. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

Describes the research program currently being implemented (some pilot plots were established in 1981-1982) by the Department of Agricultural Research in Botswana. The objectives of this program is to encourage local production of vegetables for increased self-sufficiency. Argues that the research program has led to a better understanding of the economic and technical problems faced by the vegetable producer in Botswana. The program also provides useful information on market demand for vegetables in the areas adjacent to the test plots. At the end of the program, when three years' data from all sites are available, it should be possible to give detailed recommendations on how to maximize Botswana's self-sufficiency in vegetables and to define the vegetable production potential of the different regions.

Wilson, B.H. "A Mini-Guide to the Water Resources of Botswana." In Proceedings of the Symposium on Drought in Botswana, June 5-8, 1978, pp. 59-68. Gaborone: Botswana Society in collaboration with Clark University Press, 1979.

Annotated maps and diagrams of the water resources of Botswana, intended to be suggestive rather than conclusive. Includes information on annual rainfall, rainfall disposition, annual rainfall probability, evapotranspiration and rain, rivers, dams, boreholes, hand-dug wells, hafirs, springs, aquifers, water weeds, groundwater recharge, pollution, soils, and droughts.

## LESOTHO

Lesotho's Agriculture, A Review of Existing Information. Fort Collins: Colorado State University, Department of Economics, Lesotho Agricultural Sector Analysis (LASA), Research Report No. 2, 1978.

Reviews studies of the agricultural sector under the following topics: 1) land and water conservation/reclamation; 2) manpower; 3) livestock; 4) marketing, crop production, and risk management.

Nobe, C.K. and Seckler, D.W. An Economic and Policy Analysis of Soil-Water Problems and Conservation Programs in the Kingdom of Lesotho. Fort Collins: Colorado State University, Department of Economics, LASA Research Report No. 3, 1979.

Reviews and analyzes soil and water conservation programs in Lesotho since 1935 from an economic efficiency and human welfare point of view. The report includes a chapter on methodology for evaluation of soil and water conservation programs, an overview of the natural resource base of Lesotho, a description of pre-independence and post-independence conservation programs, and a critical assessment of past programs and future options. Among the post-independence programs, the report reviews the Senqu River Agricultural Extension Project (1974-77). Among its immediate objectives were: 1) to demonstrate economic methods for run-of-river irrigation with particular emphasis on fodder production and 2) the purchase of irrigation equipment. Argues that the irrigation schemes brought negative farmer response; crop yields in all of the irrigation schemes have been disappointing, and many of the crops raised have a very low net return.

Qalabane, K. Chakela. Water and Soil Resources of Lesotho, 1935-1970, Review and Bibliography. Uppsala: University of Uppsala, Department of Physical Geography, 1973.

Overview of soil and water resources of the country. The report includes short descriptions of the development projects for soil and water management in the period under consideration (including Tsakholo Irrigation Dam, Tebe-Tebeng Valley Pilot Project, Taung Reclamation Scheme, Thaba-Phatsoa Improvement Area, Leshoele's Irrigation Project).

\_\_\_\_\_. Soil Erosion and Reservoir Sedimentation in Lesotho. Uppsala: Scandinavian Institute of African Studies, 1981.

Presents the findings of studies carried out from 1973 to 1980. The aims of these studies were 1) to document the types, rates, and extent of different erosion and sedimentation processes active within some selected catchment areas in Lesotho, 2) to improve the understanding of soil erosion problems facing Lesotho, 3) to supply some basic data to enable land-use and land-management planning.

United Nations. Food and Agriculture Organization. Qomoqomong Irrigation Scheme, by D. Layzell and B. Hatlebrekke. Technical Report, 1976.

Describes the implementation of an experimental irrigation scheme at Qomoqomong Valley. The scheme introduced the first surface irrigation system for wheat in Lesotho.

United Nations Development Program, Special Fund, with IBRD. Lesotho, Study on Water Resources Development, by Binnie and Partners. Inventory Report, Vol. 4, 1972.

The fourth volume of this six-volume final report on water resource development in Lesotho deals with irrigation. Examines irrigable land, compares existing irrigation yields with dryland agriculture. Discusses market prospects, choice of crops, and farm economics. Chapters also discuss water requirements and practical engineering requirements, including the design and location of dams. A chapter on organization is followed by sections surveying each of the eleven proposed management units.

## MALAWI

Agnew, Swanzie. The Waters of Malawi, Development Since Independence, 1966-1976. Zomba: University of Malawi, Chancellor College, Department of Geography and Earth Sciences, Occasional Paper No. 1, 1975.

Discusses the national policy on water resource development in historical perspective. The colonial policy on irrigation failed to consider ecological degradation, human diseases, and loss of fertile riverine land (Sombani, Dwangwa, Banga schemes). Several post-independence projects are examined, including a number of irrigation schemes, soil and water conservation projects, and irrigation research programs being carried out in Malawi by the Tea Research Foundation of Central Africa. Recommends that, before promoting more irrigation, the government examine 1) the high cost of irrigation relative to rainfed agriculture, 2) the availability of energy.

Chilumbo, Alifeyo. "The Response to a Planned Change: A Study of the Rice Scheme in Chief Mwambo's Area, Lake Chilwa, Zomba, Malawi." Cahiers d'Etudes Africaines 11(42)(1971):314-326.

Examines the impact of the introduction of an irrigated rice scheme that was built by the Taiwanese in 1967. The scheme introduced changes in 1) work patterns, 2) the concept of ownership of land, 3) the role of matrilineage and the extended family, 4) the concept of inheritance, 5) the role of women. One serious handicap is the lack of adequate market facilities in the area. Author concludes that the scheme has been successful in encouraging farmers to adopt new methods of farming. The behavior patterns of the demonstrators, who operated their own farms, contributed to the success of the project, as did the inclusion of the local chief in the scheme.

Kraatz, C.T.A. and Stoutjesdijk, J.A.E. "Improved Headworks for Reduced Sediment Intake." In African Regional Symposium on Small-Holder Irrigation, pp. 167-179. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

Analysis of the effects of river sediment on small-holder rice irrigation schemes in Malawi. Argues that although deforestation and other changes have accelerated sediment loads, their negative effects could have been overcome, with few exceptions, if the headworks of the schemes had been better adapted. Since headworks usually absorb a relatively large share of investment costs, they have to be made cost-effective, yet functional and durable.

Kraatz, D.B. and Stoutjesdijk, J. "Self-Help Irrigation Schemes in Malawi." In African Regional Symposium on Small-Holder Irrigation, pp. 77-86. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

A technical paper dealing with government assistance to self-help irrigation schemes in Malawi. Discusses the organization of self-help irrigation schemes and argues that their physical shortcomings largely originated from a lack of

know-how within the farm community and a shortage of financial means. Argues that government-sponsored assistance should focus on the provision of basic physical infrastructures and that farmers should be left to run their schemes on their own.

Lee, G.R. "Irrigated Upper Amazon Cacao in the Lower Shire Valley of Malawi I: NPK Factorial Trial." Tropical Agriculture 52(1)(1975):65-69.

Cacao has been grown in this area without fertilizer since 1959. The article reviews the results of a 1967 irrigated NPK fertilizer trial on Upper Amazon Cacao grown under light shade. Significant increases in the weight of wet beans per hectare were obtained from P in the absence of K and from K in the absence of P.

\_\_\_\_\_. "Irrigated Upper Amazon Cacao in the Lower Shire Valley of Malawi II: A Water Rates Trial." Tropical Agriculture 52(2)(1975):179-182.

Reports the results of a 1969-1972 irrigation trial designed to ascertain the optimum irrigation rates and frequencies on cacao grown in the lower Shire Valley.

Makato, C.J.A. "Small-Holder Rice Irrigation Schemes in Malawi: The Role of the Farmer in Irrigated Rice." In African Regional Symposium on Small-Holder Irrigation, pp. 287-294. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

The author, who is with the Malawi Ministry of Agriculture, describes 16 small-holder rice irrigation schemes done between 1968 and 1979 in areas where rice has been grown traditionally as a rainfed crop. Government objectives were to improve the living standards of the rural population, maintain self-sufficiency in rice, and export any surplus. The irrigation schemes were designed to grow two crops of rice per year, using Blue Bonnet, a high quality, early maturing variety. An improved local variety produced one crop per year. Some research has shown that small holders can grow other crops, such as wheat, maize, and beans, after the summer rice.

Malawi. Department of Lands, Valuation, and Water, Irrigation Branch, in cooperation with FAO/UNDP. Report on a Survey of Existing and Potential Farmers' Self-Help Irrigation Schemes in Liwonde, A.D.D. and Possible Development Assistance, by D.B. Kraatz, J. Stoutjesdijk, and P. Maele, 1983.

Survey of 14 self-help irrigation schemes in Liwonde. One dossier for each existing or potential scheme is appended to the report. Irrigation is practiced over only 14% of the potential irrigable area. The report reveals a great potential for farmers' self-help irrigation practices in the area. Farmers show considerable initiative and ability in developing rice schemes. The report recommends that assistance include credit, "lost investment" (such as headworks), canal systems, flood protection, and access roads.

Mphande, Crosby U. "Small-Holder Irrigation Schemes in Malawi." In African Regional Symposium on Small-Holder Irrigation, pp. 317-326. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

The author, principal irrigation engineer with the Malawi Department of Lands, Valuation, and Water, surveys the development of small-holder irrigation in Malawi since 1967. Sixteen schemes have been developed throughout the country by the Ministry of Agriculture and Natural Resources, and there is a large potential for expansion. The principal irrigated crop is rice. Due to low dry season flows in the rivers that supply irrigation water, research into alternative dry season crops (wheat, maize, and beans) is being conducted. There has been success in growing these crops in rice fields and using a water supply system that was designed for rice cultivation. Self-help irrigation schemes have suffered from 1) inadequate technical knowledge, 2) construction techniques, 3) management problems. The government is also developing a pilot borehole scheme. Hydrological data networks have been installed on all the major rivers and tributaries in the country, and adequate climatic data is being collected and analyzed.

Munro, J.M. and Wood, R.A. "Water Requirements of Irrigated Maize in Nyasaland." Empire Journal of Experimental Agriculture 32(25)(1964).

A report on experimental research on irrigated maize undertaken at Mokonga Experimental Station in Nyasaland (now Malawi). Irrigation was based on open pan evaporation. Soil moisture figures were recorded during two seasons. The importance of linking results of irrigation experiments with observed/calculated evaporation figures is discussed.

Tea Research Foundation of Central Africa. "Factors Affecting Tea Yields in Malawi with Special Reference to the Effects of Moisture Stress and Irrigation." Annual Report 1969-1970, pp. 71-130. Mlanje, Malawi, 1970.

Summarizes the results of trials on the effects of irrigation and fertilization on the growth and yield of young and mature tea. Presents data on 1) stomatal movements, 2) diurnal patterns of the relative leaf water content, 3) the effect of leaf orientation on leaf temperature, 4) the effects of day-length on shoot growth, 5) root growth studies, 6) the micro-meteorology of an extended area of tea before and after rain. Postulates a new hypothesis of synchronous shoot development to explain the periodic variations in tea yields experienced in Malawi and describes a mathematical model to fit observed yield distribution patterns.

Willat, S.T. "A Comparative Study of the Development of Young Tea Under Irrigation, I--Establishment in the Field." Tropical Agriculture 47(3)(1970):243-247.

Reports the results of a long-term experiment at the Swazi Tea Research Station, Mlanje, over root and shoot development of tea under irrigation after nine months in the field. Plant survival and root extension were greater with irrigation than without, and the type of planting material also had some effect on root growth. Shoot growth was also improved by irrigation, the plants being taller and having a greater total length of branches.



\_\_\_\_\_. "A Comparative Study of the Development of Young Tea Under Irrigation II--Continued Growth in the Field." Tropical Agriculture 48(3)(1971):271-277.

Presents further results from a long-term root-washing experiment with young tea. Root growth, both in depth and lateral spread, was better with irrigation than without after a period of 20 months in the field. Four different types of planting material were used in this experiment, and no differences were found in rooting depth although the differences in lateral spread were significant. Top growth, measured both as pruning weight and as area of cross-section of stem, showed significant increases due to irrigation but, when planting material was being considered, only pruning weight was significant.

## MOZAMBIQUE

Almeida, F.S. de and Teixeira, V. Control of Weeds in Sugar Cane Trial No. 12: Plants Irrigated, Application After Planting, Preliminary Report. Lourenco Marques: Instituto de Investigacao Agronomica de Mocambique, Weed Control Department, 1971.

Discusses the results of weed control trials on sugar cane.

Barreto, L.S. and Soares, F.A. "Provisional Zones of Mozambique According to Turc's Climatic Index of Agricultural Potential." Revista de Ciencias Agronomicas 7(1974):45-52.

Presents a map of climatic zones based on Turc's climatic index of agricultural potential. Identifies data for the index and irrigation potential for 50 sites.

Donev, P. "Soil Characteristics of Arenosols (Luvic Arenosols, Albic Arenosols) in the Shokue Region of South Mozambique." Pochvoznanie i Agrokhimiya, 18(1)(1983):16-20.

The author, a researcher with the N. Pushkaron Institut of Sofia, Bulgaria, analyzes the soil composition of the Shokue region of South Mozambique. Concludes that because of poor hydrophysical properties the soils are not suitable for irrigation. Points out, however, that they are well suited to dry agriculture, in particular for manioc, sweet potatoes, and some fruit species (e.g., cashew and mango).

Marmelo, A. "Cabo Delgado: Hora de Arranque" (Cabo Delgado: Time for a Leap Forward). Tempo 30(November 1980):16-25.

The article describes the first phase of a new irrigation project underway in Cabo Delgado, a province of Mozambique.

## S W A Z I L A N D

"From Bushveld to Modern Agriculture: Successful Farming Complex in Swaziland." Standard Chartered Review (December 1975):2-6.

Describes the development by CDC of an area of 105,000 acres in the lowveld of Swaziland since 1950. The development involved an investment of R20m. It is based on sophisticated agricultural techniques and produces crops that make a major contribution to Swaziland's exports. It provides employment for more than 5,000 Swazis and is Swaziland's most significant farming settlement.

Jones, M.J. Summaries of Work on Soil Fertility at Swaziland Experimental Sites 3: Lowveld Experimental Station, Big Bend. Mbabane: Swaziland Agricultural Research Division, Research Report No. 17, 1978.

Summarizes the results of sixteen irrigated and one dryland soil fertility experiments conducted at Lowveld Experimental Station since 1960. Provides information on responses of various crops (maize, cotton, wheat, and vegetables) to a number of fertilizers.

Mc I. Daniel, J.B. "Some Government Measures to Improve African Agriculture in Swaziland." Geographical Journal 132(4)(1966):506-615.

An overview of Swazi agricultural policy. Describes the Vuvulane irrigated farms settlement schemes (1963) and the Malkerns irrigated scheme (1954) for the cultivation of sugar cane in the northern lowveld.

"R 18 Million Project in Swaziland." The Civil Engineering Contractor 13(6)(March 1979):13-20.

Describes the project for the construction of the Fairview Dam, officially the Mnjoli Dam, being built to supply water for the cane plantations, and Swaziland's third sugar mill. The dam is located in the Tshaneni district and is part of the Imbuluzi irrigation scheme.

Swaziland. "Water." In Third National Development Plan 1978-1979/1982-1983, (197-) pp. 169-175.

This chapter reviews the previous national plan accomplishments in the water resource sector and introduces the objectives of the present plan, focusing on irrigation. Presents a program for the development of water utilization in agriculture. Proposes a number of projects, including the construction of dams and canals, and emphasizes 1) the importance of the international characteristics of Swaziland's rivers, 2) the lack of qualified technical staff, 3) poor coordination within the administrative agencies concerned with water.

U.S. Army Corps of Engineers. Swaziland Water and Related Land Resources Framework Plan, Washington, D.C.: Government Printing Office, 1981.

A conceptual framework for future water resource development in Swaziland and negotiation with the Republic of South Africa regarding development of international rivers. Provides a series of 21 baseline studies on population, soil conservation, water quality, recreation, tourism, fisheries, energy, ground water, land use, hydrology, hydropower, irrigation, water consumption, downsite screening, and the economy. The report points out that implementation of large-scale irrigation and related industrial development can greatly contribute to the achievement of government goals concerning employment, revenue, foreign exchange imports, and environmental degradation. Concludes that irrigation is the key to the economic feasibility of water resource development in the country. Includes 13 maps on transport and land tenure, the physiography and hydrology of the nation, and a 71-item bibliography (1965-1980).

United Nations. Food and Agriculture Organization. Water Law in Selected African Countries (Benin, Burundi, Ethiopia, Gabon, Kenya, Mauritius, Sierra Leone, Swaziland, Upper Volta, Zambia), by Dante A. Caponera. Legislative Study No. 17, pp. 206-223, 1979.

This study contributes to a global inventory of national experiences in the field of water law and administration. In recent years, water laws and institutions have undergone fundamental modifications in many countries of Africa. The selection of the country studies in this volume was made, on the availability of data in the FAO's legislation branch on the basis of geophysical characteristics, juridico-political history or institutional organizations.

\_\_\_\_\_. Food and Agriculture Organization. Reconnaissance Irrigation Study, Lusushwana River, Swaziland. Technical and Economics Feasibility Report, by Engineering and Power Development Consultants Ltd., UK, 1980.

Assesses the relative merits of the options for development of the water resources of the Lusushwana River: a single purpose hydro-electric scheme or, alternatively, a project which will combine development for energy generation with irrigation.

\_\_\_\_\_. Food and Agriculture Organization. "Monitoring a Sugar Outgrower Project: Vuvulane, Swaziland," by E. Cobban. In Economic and Social Development Paper No. 12, pp. 187-201, 1981.

Vuvulane Irrigated Farms is a small-holder, irrigated sugar project of 2500 ha. which shares processing facilities with neighboring sugar estates. The production and harvesting of sugar cane is closely controlled by project management. The monitoring system is an essential means of achieving this close control. It ensures a timely supply of services to the farmer and a constant supply of good quality cane to the factory. It also helps to maintain farmers' incomes at a high level. The monitoring sub-systems focus on 1) water distribution, by which efficient water management is achieved, 2) the provision of mechanical services and purchased inputs, which ensures efficient machinery use and high yields, 3) on the progress of cane harvesting operations, which enables the harvesting timetable to

be adhered to, and sugar quality to be maintained. The system involves very detailed recording and the use of numerous forms and is operated by project staff.

Villiers, A. de. "A New Approach to Planning and Developing of Small Holder Irrigation Schemes in Southern Africa." Southern African Journal of African Affairs 7(2)(1977):107-114.

The author, who is with the Bureau for Economic Research, Bantu Development, Pretoria, recommends that small-holder irrigation schemes be addressed by agricultural policy. Discusses the successful experience of Vuvulane irrigated farms in Swaziland. Argues that an integrated framework aimed at providing small holders with means and incentives to achieve commercial production is the key of its success.

## TANZANIA

Berry, Leonard and Kates, R.W. Planned Irrigated Settlement: A Study of Four Villages in Dodoma and Singida Regions, Tanzania. Dar Es Salaam: University of Dar Es Salaam, Bureau of Resource Assessment and Land Use Planning, BRALUP Research Paper No. 10, 1970.

Report of a study conducted in 1968 and 1969 on 4 village-scale irrigation schemes in the Singida and Dodoma regions of Tanzania. Describes land utilization and irrigation practices in these villages. Draws some conclusions from these examples that may have wider applicability. Argues that such small schemes have to be part of district and regional development programs. Concludes that economic incentives, such as attractive markets for the products, are the prerequisites for successful village irrigation schemes. Recommends that demonstration farms and training be carried out and that new cash crops and varieties well-suited for irrigation be introduced.

Bos, M.G. and Slabbers, P.J. "Integrated Development Plan for Morogoro Region, Tanzania: III--Agricultural Water Development." In Annual Report of the International Institute for Land Reclamation and Improvement, pp. 15-46. Wageningen: International Institute for Land Reclamation and Improvement, 1974.

The authors are members of the Morogoro Planning Team. The team was assembled by the Directorate of International Technical Cooperation of the Netherlands to assist the government of Tanzania in preparing the integrated regional development plan of Morogoro region, in 1973. Presents a detailed analysis of irrigation practices and potential in the region. In particular discusses the four types of irrigation schemes present in Morogoro: 1) traditional irrigation, 2) village irrigation schemes, 3) irrigated state farms, 4) irrigated private estates. Recommends that priority be given to the development of a few relatively large village irrigation schemes for the production of vegetables and rice.

East African Academy, Nairobi, Kenya. The Role of Water Resources in Development: Proceedings of the 13th Annual Symposium of the East African Academy Nairobi, Kenya, September 1977. Edited by J.B. Castelino and C.P.M. Khamala. Nairobi: National Academy for Advancement of Arts and Sciences, 1977.

Contains papers on meteorological, hydrological, environmental, and public health aspects of irrigation and water management in East Africa (especially Kenya and Tanzania).

Hazelwood, A. and Livingstone, I. "Complementarity and Competitiveness of Large- and Small-Scale Irrigated Farming. A Tanzanian Example." Oxford Bulletin of Economics and Statistics 40(3)(1978):195-208.

A linear programming study of the choice between paddy production in the Usangu Plains of Southern Tanzania through large (state) farms and small-scale village

production. The study argues that these are in fact not alternatives, but ought to be combined to maximize the area under paddy.

Hazelwood, A.D. and Livingstone, I. Irrigation Economics in Poor Countries: Illustrated by the Usangu Plains of Tanzania. Oxford: Pergamon Press, 1982.

A study of the Usangu Plains of southwest Tanzania done by two economists in the mid-1970s. Linear programming models are used to determine water demand; water supply determination is discussed; and the economics of water storage are examined. The economic structure of the Usangu Plains is analyzed, and its productive potential calculated. Issues of economies of scale are treated in relation to small-scale village irrigation. Interdependence (of external economies and diseconomies) is discussed. Finally, the relationship between economics and technology in irrigation planning is considered.

Kaduma, J.D. "Water as a Constraint on Agricultural Development in the Semi-Arid Areas of Tanzania." Water Supply and Management 6(5)(1982):417-430.

Reviews the utilization of resources in the semi-arid areas of Tanzania. Argues that groundwater irrigation is regarded as the answer to stabilization of agriculture in those areas because 1) rainfall is very unpredictable and sporadic, precluding storage and run-off; 2) the two major rivers, Pangani and Great Ruaka, are regulated for hydroelectric power production, leaving very little water for irrigation purposes, 3) many streams are ephemeral or brackish, 4) the black clay soils impede drainage.

Mbawala, P.P. "Irrigation Development in Mainland Tanzania: The Issue of Farmer Local Organization--A Suggestion." Agricultural Administration 6(2)(1979):99-110.

Overview of irrigation policy in Tanzania. In 1974 the TANU political party (Chama) decided to give new emphasis to small-scale irrigation projects. Focuses on the issue of small-scale irrigation projects. The author suggests models of organizing and operating small-scale irrigation systems based on the Tanzanian village organization.

\_\_\_\_\_. "Irrigation Development and Peasant Participation in Tanzania." Eastern Africa Journal of Rural Development 13(1/2)(1980):68-91.

The future of agricultural production in Tanzania depends on irrigation. This paper argues that peasant organizations should be responsible for the local control of irrigation projects. Without active farmer participation, most of the government-initiated and constructed small-scale irrigation schemes have been unsuccessful.

\_\_\_\_\_. "Irrigation Management Alternatives for Tanzania." Ph.D. dissertation, University of Missouri, 1981.

The author shows that in Tanzania irrigation remains an innovation for which peasants lack appropriate social and technical skills, and the problem is compounded by a dearth of qualified and seasoned irrigation technicians. Recommendations are made for the improvement of this situation.

Mrema, Geoffrey C. "Development of Small-Holder Irrigation in Tanzania: Problems and Prospects." In African Regional Symposium on Small-Holder Irrigation, pp. 307-316. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

The author, head of the Department of Agricultural Engineering and Land Planning, University of Agriculture, Morogoro, reviews the development of small-holder irrigation in Tanzania over the past three decades. Makes specific reference to three government-aided and constructed schemes, namely: Mlali, in Morogoro region (65 ha); Mobo, in Tanga region (220 ha); and Mto wa Mbu, in Arusha region (220 ha). Although the government invested heavily in these schemes, their performance has been disappointing. The main problems are shown to be the lack of technical expertise among both the farmers and the scheme management staff. Compares these schemes to the traditional small-holder irrigation schemes (such as those found on the slopes of the Kilimanjaro and Meru Mountains) and to the large-scale irrigation schemes, like Mbarali (3,000 ha) and Dakawa (2,000 ha). Because of the high capital costs of building irrigation schemes (over US \$5,000 per ha, whether small-holder or large-scale) the report argues that irrigation is unlikely to be viable unless the technical and management skills are also made available.

Nkonoki, Simon R. "Irrigated Agriculture." In Cooperation in Energy Development in Eastern Africa, pp. 170-171. Bergen: Christian Michelsens Institutt for Videnskap og Aandsfrihet, Development Research and Action Programme, DERAP Publication No. 166, 1982.

Argues that most of the Kagera River is not suitable for irrigation because of poor soil, and land elevation. Among others, describes the Kyaka-Kakono Irrigation Project in Tanzania (16,800 ha) to be implemented for growing rice, maize and soya beans. The project, which includes an agronomic research and seed multiplication farm, will take six years to establish.

\_\_\_\_\_. Regional Development Planning of the Kagera River Basin in Eastern Africa under the Kagera Basin Organization. Bergen: Christian Michelsens Institutt for Videnskap og Aandsfrihet, Development Research and Action Programme, DERAP Publications No. 167, 1983.

A case study of hydropower development planning and related environmental impacts. Gives estimates of the power requirements for irrigated agriculture east and south of Lake Victoria.



Norconsult, A.S. and Electrowatt Ltd. Kagera River Basin Development, Phase II: Burundi, Rwanda, United Republic of Tanzania, Indicative Basin Plan. United Nations (acting as executing agency for UNDP), Technical Report Vol. 13, 1976.

The plan reflects three basic premises that derive from the sectoral and prefeasibility studies which were carried out under the Phase II program: 1) self-sufficiency in food must be the first objective of regional development; 2) subsistence agriculture, which is the primary economic activity in the region, needs the provision of modern inputs. Recommends that hydropower be used to produce fertilizer. Production would more than meet local needs; the surplus could be exported. Discusses project development of irrigated agriculture largely in the lower Kagera valley of Tanzania (Kyaka, Kajunguti, Ikimba/Ngono, Nkenbe projects).

Pocs, T. "Bioclimatic Studies in the Uluguru Mountains (Tanzania, East Africa)." Acta Botanica Academiae Scientiarum Hungaricae 20(1/2)(1974):115-135.

Describes the microclimate of four natural plant communities on the slope of Mt. Bondwa and compares those with that of neighbouring secondary vegetation, mainly maize crops. Removal of a protective vegetation cover led to soil erosion, strong insolation, winds, and increased evaporation. Concludes that well-designed reforestation (windbreaks or use of shade trees) would save large amounts of irrigation water.

Ritoine, E.L., Lyatuu, H.A., Mosha, C.J., Sambai, L.M., and Mollel, S.L. "Chemical Control of Weeds in Transplanted Rice." In Proceedings (of the) British Crop Protection Conference, Arusha, Pest Research Institute, pp. 875-882.

In trials in the irrigated basin of the River Mombo, Northern Tanzania, bentazone + propanil at a 4 and 5 kg mixture/ha provided the best weed control in transplanted rice and was superior to hand weeding. The other herbicides tested were generally unsatisfactory at the rates tested. No treatment affected the yield or quality of the crop.

Sachansky, S. "Testing of Some Soybean Varieties Under Irrigation Conditions in the United Republic of Tanzania." Tropical Grain Legume Bulletin 5(1976):36-38.

Discusses the findings of two trials of soybeans grown under irrigation in 1974 in Miwalani Experimental Station. Recommends further study on variety testing, rate and time of irrigation, planting time, population density, fertilizer rate, types and time of application of macro- and micro-elements.

Sarma, S.V.K. "Control of Soil Erosion in Rural Areas of Tanzania." In The Role of Water Resources in Development. Proceedings of the 13th Annual Symposium of the East African Academy, Nairobi, Kenya, September 1977, pp. 200-205. Edited by John B. Castelino and P.M. Khamala Canute. Nairobi: National Academy for Advancement of Arts and Sciences, 1977.

Discusses factors affecting the source of eroded soil. Outlines steps to be taken to alleviate the problem. Concludes by highlighting research needs, both in data collection and the development of mathematical models.

Schiller, E.J. "Hydrological Design Studies on the Sinza River Project at Ubungo, Tanzania. Part 2: Open Channel Computations." In The Role of Water Resources in Development. Proceedings of the 13th Annual Symposium of the East African Academy, Nairobi, Kenya, September 1977, pp. 206-214. Edited by John Castelino and P.M. Khamala Canute. Nairobi: National Academy for Advancement of Arts and Sciences, 1974.

Preliminary computations involved in the appraisal of the Sinza River Project at Ubungo, Tanzania. The project concerns the renovation and improvement of the existing hydrological station, including spillway flow measuring devices, experimental pumps, boreholes, a dam, a weir, and a small irrigation plot.

United Nations. Food and Agriculture Organization. Survey and Plan for Irrigation Development in the Pangani and Wami River Basins, United Republic of Tanzania: Soils, by N. Mikenberg, G.R. Suggett, and J.W. Dewis, 1968.

Report on soil surveys carried out in six major areas of the Pangani and Wami Valleys between June 1964 and December 1966. The report includes general descriptions of each area surveyed, an explanation of the main problems, and a description of the soil units surveyed with comments on their suitability for irrigation agriculture. Includes findings and recommendations on irrigation practices and problems for each area.

\_\_\_\_\_. Food and Agriculture Organization. Report to the Government of Tanzania on the Economics and Planning of Irrigation, based on the work of Robert M. Boersee. FAO No. TA 3096, 1972.

Detailed overview of the history of irrigation in Tanzania: present situation and future prospects. Finds that at present about 4 percent of all cultivated land is intermittently irrigated, most of it by small holders.

\_\_\_\_\_. Development Program in cooperation with United Kingdom, Overseas Development Group; and University of East Anglia. Iringa Region, Tanzania--Integrated Rural Development Proposals for the 3rd Five-Year Plan, 1976-1981, 1976.

Contains proposals for the five-year plan for development of Iringa Region. The role of the UNDP is viewed as 1) to support the regional management team in preparing drafts of the regional plan to go before the Regional Development Council; 2) to provide feedback to the government. Focuses on a package of jointly planned projects in key sectors that replaces the previous independent sectoral programs at each planning level (the village, the sub-district planning area, the district, and the region).

. Food and Agriculture Organization. Report to the Government of Tanzania on Irrigation Suitability Survey, Semi Sub-Irrigation System, and Gravel Cast Techniques, 1977.

Describes an assignment undertaken in Tanzania to assist the government in a variety of subjects connected with soil surveys, irrigation methods, and improved techniques in water-supply installation. Reports the findings of an irrigation suitability survey in various districts of the country. Most of the arable lands are affected by one of the following adverse conditions: alkalinity, salinity, insufficient drainage, or general sandy conditions underlain by clay. Concludes that irrigation in Tanzania is problematic, and that it is better to concentrate on rainfed farming on high-potential areas than to introduce irrigation.

                    . Food and Agriculture Organization and UNCTAD. An Interim Report on the Hydrogeology of Zanzibar Island, Tanzania, 1982.

The report sets out the present state of knowledge on the hydrogeology of Zanzibar Island. Discusses two major assessment projects concerned with the suitability of irrigation of the entire Bumbwi scheme of central Zanzibar. The projects were carried out during the last decade by the Ministries of Agriculture (Kilimo), and Water, Energy and Minerals (Maji) with the assistance respectively of FAO and UNCTAD.

## Z A M B I A

Balek, Jaroslav. Water Balance of the Zambesi Basin. Lusaka: National Council for Scientific Research, 1971.

The report is intended to provide the relevant information about the hydrological behavior of the Zambesi River network. The author deals primarily with the part of the Zambesi Basin within Zambia, but includes information about the non-Zambian part of the basin. Argues that calculations were made difficult by inadequate records and lack of communication with the neighboring countries. Stresses the need for further research before any local hydrological data can be calculated and applied to industrial or agricultural projects.

Banda, Moses. "A Consideration of the Consolidation Stage: Siatwiinda Pilot Scheme Experiences in Gwembe Valley, Zambia." In African Regional Symposium on Small-Holder Irrigation, pp. 391-400. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

Discusses the rationale for irrigation pilot projects as a means of introducing perennial crop production into the Gwembe Valley, in particular the consolidation stage phenomenon. Describes the history of the traditional land use system and the experiences of the Siatwiinda pilot irrigation scheme. Concludes that irrigation interventions in the small-holder sector have to be geared to the enhancement of the virtues of existing systems.

Clayton, E.S. A Comparative Study of Settlement Schemes in Kenya. London: University of London, Wye College, Agrarian Development Unit, Occasional Paper No. 3, 1978.

Study undertaken to assist the government of the Republic of Zambia with the design of an irrigated settlement scheme. The aim is to present information about selected settlement schemes in East Africa, particularly their management and operation. Discusses the planning and technical aspects of settlement schemes. Describes the principal settlement schemes in Kenya, the Mwea, Perkerra, Ahero, Buryala and Tana irrigation schemes and the Million Acre settlement scheme.

Great Britain. Ministry of Overseas Development, Land Resources Division. Land Resources of the Northern and Luapula Provinces, Zambia--A Reconnaissance Assessment, by J.E. Mansfield, J.G. Bennett, R.B. King, D.M. Lang, and R.M. Lawton. London: Land Resource Study No. 19, 1975.

The report is based on the results of a geomorphological/soil/vegetation survey, linked with aerial photographs. Identifies a number of sites suitable for annual and perennial crop production under quantity-fed and overhead irrigation systems. A preliminary assessment of the area's development potential is made in relation to environmental factors, crops, livestock, forestry, and farming systems.

Honisch, O. "Water Conservation in Three Grain Crops in the Zambezi Valley." Experimental Agriculture 10(1974):1-7.

Discusses the results of a three-year conservation trial in the Zambezi Valley in an area of high temperatures and low, often poorly distributed, rainfall, with low infiltration and high evapotranspiration rates. As a result of these conditions, farmers often produce grain crops yielding 200-300 kg/ha; considerable increases could be obtained by using simple water conservation methods. Of four treatments, tie-ridges made before the start of the first rains consistently gave the heaviest yields. Mean yields of the three crops under trial (maize, sorghum, and bulrush millet) were higher on tie-ridges than on conventionally prepared seedbeds by 168, 159, and 17 percent in the 1968-1969 to 1970-1971 seasons.

Levy, C.A. Cost and Benefits of Introducing Irrigation in a Farm Production Programme. Mazabuka, Zambia: National Irrigation Research Station, 1979.

The report is organized into three parts. The first part presents the sources of data and the auxiliary calculations. Data were obtained by the planning unit of the Ministry of Agriculture and Water Development. The second part shows the figures estimated according to the procedures explained in the initial section. The third part shows the calculated net present value, the cost benefit ratio, and the internal rate of return.

Manshard, W. "Bewässerungsanbau auf den Kafue-Flats in Sambia" (cultivation under irrigation on the Kafue Flats in Zambia). In Siedlungs- und Agrargeographische Forschungen in Europa and Afrika. Wiesbaden: F. Steiner, 1971.

Discusses water-resource surveys executed under development aid projects in the flats of the Kafue River of Zambia. Identifies the need to 1) improve the natural drainage, 2) develop cheap irrigation methods, 3) improve the soil structure. Advocates further agro-technical and socio-economic studies that deal with irrigation potential.

Minderhoud, P. "Planning of Flood Control and Land Use in Relation to Water Management in the Lower Kafue Catchment Area in Zambia." In Eleventh Congress on Irrigation and Drainage, Part 3, pp. 543-565. New Delhi, India: International Commission on Irrigation and Drainage, 1981.

Describes a mathematical model which reproduces water levels and flows in a network of nodes. The model was used to develop water management rules for the existing conditions in the lower Kafue catchment area and to predict the consequences of further irrigation development.

National Council for Scientific Research. The Water Resources Inventory of Zambia: Water Resources Research Report. Lusaka: National Council for Scientific Research, 1977.

Provides a systematic assessment of the country's water requirements and the available water resources for the Luangwa River basin. The study showed that the

basin has ample water. (Only 10% of the surface water would be required to meet the annual demand for the next decade.) Describes the development and application of a "Water Resources Distribution Mathematical Model," which distributes the discharges at a station near the mouth to fifteen other points on the mainstream. The distribution model takes into account the areal distribution of the rainfall as well as the physiographic conditions. Concludes by stressing the need to establish an optimal hydrometeorological network for the basin before initiating any project in the area.

Nelson-Richards, M. Social Change and Rural Development: Intervention or Participation, A Zambian Case Study. Washington, D.C.: University Press of America, 1982.

Discusses the introduction of an irrigation project to small-scale farmers who used to be subsistence farmers; compares the economic activities of these farmers with those of another group of small-scale farmers who did not have the use of irrigation facilities. Discusses the organizational and administrative aspects of the project with emphasis on the role of political leaders and urban elites in furthering rural development. Concludes by analyzing the gulf between the project organizers and the farmers and blames this situation on the relationship between the political leaders and the rural organizers. Recommends that the political leaders allow farmers to participate in decisions about rural development projects.

Richards, M.N. "Experiment on Rural Development in an African State: Zambia, the Chunga Irrigation Scheme." Journal of African Studies 8(4)(1981):146-162.

Argues that in Zambia, as in other African countries, rural development is managed by the urban elite. As such lack of political will and absence of progressive political decisions characterize the rural development policy in the country. An attempt to make the Chunga scheme a fully self-help project from the start has failed because the peasants have been expected to start with nothing.

Scudder, Thayer. "Kariba Dam: The Ecological Hazard of Making a Lake." Ekistics 29(173)(1970):260-261.

Analysis of the detrimental impact of the Kariba Dam on down-river agriculture. The author argues that the Kariba project was essentially a uni-purpose scheme for generating power. The measures recommended by the Department of Agriculture were directed only at erosion control and agricultural intensification; they did not take the farming population into consideration. The author concludes that, in general, technical or ecological solutions to problems of environmental degradation are not of much use unless it is understood and implemented by the relevant people at the local and national levels.

Siakantu, J.B. and Qasem, M.A. "Design of a Small-Holder Irrigation Scheme in the Gwembe Valley in Zambia." In African Regional Symposium on Small-Holder Irrigation, pp. 233-244. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

Describes the irrigation project organized in 1982 by the government, in collaboration with the FAO, to develop quick-yielding and low-cost irrigation along Lake Kariba. Following agronomic trials and socio-economic studies, a simple basin irrigation system with minimum structures was designed. The layout was constructed by hand at Chiyabi on the drawdown land and put to a test in 1983 to find out whether it would be socially acceptable and economically viable. Portable low-lift pumps were used to deliver water to the field. Three sub-categories of farmers were involved in the test: 1) village elders, 2) a widow, 3) school dropouts. Preliminary results indicate that the latter two categories would react favorably to such a system.

United Nations. Food and Agriculture Organization. Small-Scale Irrigated Horticulture Development and Training; Chapula, Zambia; based on the work of Federico Bonetti. Technical Document, 1973.

Reports on the UNDP/FAO Chapula irrigation project, in the northern catchment of Kafue River basin, for the period 1972-1973. The long-term objective of the project was to achieve national self-sufficiency in horticultural production. The short-term objectives included: 1) to assist the government in running training courses; 2) to assist vegetable growers in establishing and managing an efficient growers' association; 3) to demonstrate varying techniques of water application to horticultural crops for small-scale producers; 4) to collect and analyze data relating to water use and to agronomic and economic aspects of horticultural production. This technical document analyzes: 1) soil-water-plant relationships, 2) crop irrigation requirements, 3) soil-water distribution, 4) evaluation of water costs.

\_\_\_\_\_. Food and Agriculture Organization. Small-Scale Irrigation Development and Training; Chapula, Zambia; Horticultural Practices, based on the work of J. Classens. Technical Report No. 1, 1975.

The report, prepared for the government of Zambia by the FAO, is a description of the first six years of the Kalulushi project, in Copperbelt province, which has attempted to develop intensive vegetable production under irrigation by local growers. The project has provided training, basic mechanization services, supply of inputs, and a comprehensive internal marketing scheme. The report describes existing and recommended agricultural practices. A five-year crop-rotation system has been developed to overcome nematodes, soil-borne diseases, and declining soil fertility. Emphasis is placed on good nursery and field practice. Concludes by recommending farmers' involvement.

\_\_\_\_\_. Food and Agriculture Organization. A Zambian Handbook of Pasture and Fodder Crops, by T.K. Thorp, 1979.

A manual which attempts to bring together 25 years of pasture research in Zambia. Including 1) irrigated crops and pastures; 2) non-irrigated improved sown pastures, fodder crops, and the veld.

\_\_\_\_\_. Food and Agriculture Organization. Water Law in Selected African Countries, (Benin, Burundi, Ethiopia, Gabon, Kenya, Mauritius, Sierra Leone, Swaziland, Upper Volta, Zambia). Edited by Dante A. Caponera. FAO Legislative Study No. 17, pp. 243-261, 1979.

This study contributes to a global inventory of national experiences in the field of water law and administration. In recent years, water laws and institutions have undergone fundamental modifications in many countries of Africa. The selection of the country studies in this volume was made, first of all, on the availability of data in the FAO's legislation branch and on the basis of geophysical characteristics, juridico-political history or institutional organizations.

\_\_\_\_\_. Food and Agriculture Organization. Joint FAO/German/Dutch Consultancy Mission on Irrigation Potential in Zambia. Mission Report, (1979).

An extensive survey was conducted on data provided by the administrative units concerned with research and development of agriculture and data directly collected during the mission's visits to farms and agricultural projects. The report consists of 3 parts: Part 1 deals with the assessment of climatic, soil, water, and crop resources, and attempts a detailed classification of tracts of land for irrigation; Part 2 deals with the economic and administrative aspects of irrigated crop production; Part 3 gives the mission's conclusions and recommendations. The report recommends active government involvement to encourage irrigation, especially small-scale schemes. Sees greater human and economic constraints to promotion of irrigated agriculture. Recommends increasing productivity of rainfed practices in the first instance with selected development of irrigation for crops in high demand, such as wheat and vegetables.

Wood, Adrian P. "The Kaleya Small Holders' Scheme: A Preliminary Appraisal." In African Regional Symposium on Small-Holder Irrigation, pp. 221-231. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

The author, who is with the Rural Development Studies Bureau at the University of Zambia, describes the Kaleya small holders' scheme (begun in 1980) and the resettlement of the 302 small holders, which are scheduled to be completed in 1988. The scheme will use water from the Kafue River to cultivate 1,885 hectares of sugar cane for the Nakambala sugar estate. Two-thirds of the cane will be grown by the small holders, each with holdings of four hectares. Discusses potential problems and recommends careful selection of and training for the small holders.



Zambia. Department of Agriculture. Production and Fertilization of Natural Flood Plain Sward Under Irrigation in the Western Province, by J. Kulich and S.K. Kulich. Mongu, Zambia: 1973.

Summarizes the results of the agronomical trials conducted by the Department of Agriculture at two pasture sites in the western province. The trials concerned the effect of different fertilizers, the influence of irrigation, the production and chemical composition of silage and hay, the influence of cutting frequency and seasonal distribution of grass output.

Zukas, Simon B. The Chunga Irrigation Scheme: A Low-Profile Approach to Rural Development. Lusaka: Simon Zukas and Partners, 1973.

Reports on the first three years of the self-help Chunga irrigation scheme. The report questions the adequacy of credit and marketing incentives for promoting long-term self-sustaining agriculture and possibility of replication of the experience throughout Zambia.

## Z I M B A B W E

Blackie, Malcolm J. and Schneeberger, Kenneth C. "An Irrigation Investment Simulator." Rhodesian Journal of Economics 5(3)(1971):11-15.

Uses the irrigation investment simulator (developed at the University of Missouri) to examine the profitability of irrigation. The simulator incorporates maize response to soil moisture stress and the investment required for irrigation.

Blackie, Malcolm J.; Hungwe, Alois; and Rukuni, Mandivamba. "Irrigation Development and Water Management Strategies in Kenya and Zimbabwe: A Report Prepared for the Ford Foundation, Eastern and Southern Africa Office." Nairobi: 1984.

Reviews the literature on climate and water resources. Examines general issues of irrigation development and water management. Argues that the major policy issue in eastern and southern Africa is increasing the productivity of crops and livestock. Discusses in detail the current and future state of irrigation in Kenya and Zimbabwe, including 1) the potential for large- and small-scale irrigation and water management; 2) the policies and activities of agencies active in this field, including government departments, parastatals, aid donors, and non-governmental organizations. Provides recommendations on 1) the priority that the Ford Foundation should accord to irrigation and water management in Kenya and Zimbabwe over the next 5-10 years; 2) priorities for the foundation in the general area of irrigation and water management.

"Developing Irrigation in Zimbabwe." African Water and Sewage (June 1983):23-24.

Discusses the results of a 1982 feasibility study for the development of up to 40,000 hectares of irrigated land in the Chisumbanje area of the lower Sabi River in southeast Zimbabwe. Also discusses the findings of a survey conducted among the settlers on the project and on its periphery. These studies indicate that the minimum size of a farm under wheat and cotton should be 2-3 hectares and that settlers should have the opportunity to work small irrigated vegetable plots adjacent to their villages. Predicts that within 17 years there will be 25 such villages. Concludes by stressing that the project has important national implications for food security and employment issues.

Elwell, H.A., and Stocking, M.A. "Rainfall Parameters to Predict Surface Runoff Yield and Soil Losses from Selected Field-Plot Studies." Rhodesia Journal of Agricultural Research 11(1973):123-129.

A rainfall parameter which represented the cumulative seasonal momentum values of all storms proved to be the best predictor of direct surface runoff yield from selected field plots on the Rhodesian highveld. Argues that there was a close relationship between soil loss and surface runoff quantities, this suggests that prediction equations can be developed for both quantities from the same data source. In addition, rainfall parameters proved to be more dependable as estimators of runoff than of soil loss. These two observations are contrary to previously reported results.

Fullstone, M.J.; Metelerkamp, H.R.R.; and Du Toit, A.A. "The Effect of Bicarbonate Irrigation Waters on Some Properties of Two Rhodesian Soils." Rhodesian Journal of Agricultural Research 13(1975):113-122.

Presents the results of experimental irrigation of sand and clay soils with bicarbonate-rich water having a low sodium absorption ratio (SAR) and no residual  $\text{Na}_2\text{CO}_3$ . Both soils showed a rise in pH and exchangeable sodium percentage (ESP). The changes in the sand were greater than those in the clay. Rise in conductivity was approximately the same for both soils and was attributed to water-soluble Na salts. The precipitation of  $\text{CaCO}_3$  and  $\text{MgCO}_3$  was an effective liming mechanism which, in addition, caused an increase in the SAR of the water and resultant increase in soil ESP.

Hawkins, P. and Hanratty, B.F. "Tribal Trust Land Development Corporation Limited: Rural Development in Rhodesia: Planning and Development in the Victoria Province." Zimbabwe Journal of Economics 1(2)(1979):104-108.

Discussion of two development models in the tribal trust lands (now called communal areas) that were designed to relieve land pressure through planned development.

Hearn, A.B. and Wood, R.A. "Irrigation-Control Experiments on Dry-Season Crops in Nyasaland." Empire Journal of Experimental Agriculture 32(125)(1964):1-17.

The authors discuss the findings of irrigation studies at Makanga. The article focuses on the development of a method of irrigation control suitable for winter annual crops. An efficient method of irrigation control is needed to show accurately how much water to apply to a crop and how frequently to apply it. Tentative irrigation systems for beans, onions, maize, and wheat are presented.

Hungwe, Alois. "Soil Surveys for Small-Holder Irrigation: Some Observations from Zimbabwe." In African Regional Symposium on Small-Holder Irrigation, pp. 105-112. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1980.

The paper examines the criteria used to assess soils for irrigation and, on the basis of those criteria, argues that most of the soils under small-holder irrigation in Zimbabwe are of limited suitability for irrigation. Argues that most of the explanations for the decline in popularity of small-holder irrigation in Zimbabwe have concentrated on social issues. While social issues should not be overlooked, the possible deterioration of soil fertility or other soil properties and consequent decline of yields should also be considered. Concludes by emphasizing the necessity of periodic examinations of irrigated soil in order to monitor possible deterioration.

Mupawose, Robbie Matongo. "Irrigation in Zimbabwe: A Broad Overview." In African Regional Symposium on Small-Holder Irrigation, pp. A1-14. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

Argues that irrigation must be used to combat weather hazards. Discusses the structure and performance of existing irrigation schemes: 1) large private commercial estates--Triangle, Hippo, Mkwesine (in the southeastern lowveld), and Mazoe Citrus Estates; 2) medium-sized private commercial schemes; 3) state schemes under the responsibility of the Agricultural and Rural Development Authority (ARDA); 4) settlement schemes--Hippo Valley, Mkwesine, Middle Sabi, Chisumbanje, Sanyati, and Antelope; 5) communal schemes. Argues that irrigation development should not be implemented on the basis of rigid cost criteria but on the basis of the government's overall agricultural and national policy objectives and equity considerations. The ideal policy for irrigation development is one that will contribute to food production, economic returns, and equity goals and help the agricultural sector to minimize the adverse effects of seasonal droughts, which are common in Zimbabwe. Concludes that there is significant potential for irrigation in Zimbabwe, and the government should focus its attention on the major policy issues.

Pazvakavambwa, S. "Relationship Between Design of Small-Holder Irrigation Systems and Their Subsequent Operation Criteria: The Zimbabwe Experience." In African Regional Symposium on Small-Holder Irrigation, pp. 95-98. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

Reviews some of the major problems in designing small-holder schemes in Zimbabwe and the attempts that are being made to streamline the designs. Argues that the design of small-holder irrigation systems should include built-in flexibility to accommodate changes in cultivation practices during the life of the project.

\_\_\_\_\_. "Management of Small-Holder Irrigation Schemes in Zimbabwe: The Committees' Approach." In African Regional Symposium on Small-Holder Irrigation, pp. 421-426. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

Describes the development of irrigation schemes in Zimbabwe during the last 50 years. The schemes were established to increase food security in low rainfall areas, thus reducing or minimizing inter-regional maize transfers. A weakness of the schemes has been the lack of programs training farmers and preparing them to take over and manage the schemes. A parallel development has been that irrigation schemes in communal areas have remained dependent on government support.

Pearce, G.R. "Water Flow Analysis on a Small-Holder Irrigation Scheme: Initial Results; Nyanyadzi, Zimbabwe." In African Regional Symposium on Small-Holder Irrigation, pp. 353-368. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

Presents basic data on water flow at various points in a typical small-holder irrigation scheme. The two aims of the water-flow study are: 1) to provide a design data base for the planners of future small-holder irrigation schemes in Africa, and 2) to identify lessons that can be learned from one reasonably successful scheme. The initial results show that the Nyanyadzi scheme is suffering from the classic problem of the "top-end" farmers using more water than those at the "tail-end" of the irrigation canals. Discusses the need for replacing observer readings on water flow with an automatic gaugeboard and data-logger system.

Reid, M.G. "Crops Appropriate to the Sebungwe Region." Zimbabwe Agricultural Journal 79(5)(1982):159-160.

The author describes agricultural practices and crop-patterns in the three main crop production zones in the Sebungwe region. Argues that irrigation is not likely to appeal to cotton farmers who are doing well under dryland conditions.

Roder, Wolf. "Zimbabwe, Anticipation of Economic and Humanitarian Needs: White and Black Irrigation in Rhodesia." In Transition Problems in a Developing Nation. Washington, D.C.: African-American Scholars' Council, Occasional Paper No. 8, 1977.

Argues that new investment in small-holder irrigation projects must consider the long-term viability of such projects and their contribution to the national economy. Concludes that the greatest opportunities for African agricultural settlement exist in the underutilized European farms of the high rainfall areas, not in irrigation development areas; irrigation investment is not the most profitable use of scarce capital resources.

Rukuni, Mandivamba. "Cropping Patterns and Productivity on Small-Holder Irrigation Schemes." In African Regional Symposium on Small-Holder Irrigation. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

Discusses crops grown on small-holder irrigation schemes in Zimbabwe. Differences in cropping patterns exist between various types and provinces. The diversity of these cropping patterns is shown by province, and differences in yields and cropping intensities are discussed. The paper presented data on the productivity of different schemes. These data also show levels of marketing of produce by farmers and indicate that food crops, such as maize, are frequently marketed through informal channels. The effect of plot size on cropping patterns and yields is discussed based on 1981 data from the Nyanyadzi irrigation scheme.

\_\_\_\_\_. "Household Analysis of Resource Base and Use on Small-Holder Irrigation Schemes." In African Regional Symposium on Small-Holder Irrigation, pp. 401-408. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

The paper discusses three main types of small-holder irrigation schemes in Zimbabwe. These are (a) the older government schemes, (b) the newer government schemes, and (c) those run by ARDA (Agricultural and Rural Development Authority), a parastatal, as part of a large state farm. The older government schemes are more "intensive," and individual families have more land than those on the newer "supplementary" schemes. The farmers on supplementary schemes integrate irrigation with rainfed agriculture. Families generally face a number of resource constraints. First is the lack of draft power on government schemes. ARDA farmers have access to tractors. Farmers also generally face labor shortages at certain times of the year, especially in the production of crops like cotton or tomatoes. Farmers also face cash shortages at times. This affects the use of purchased inputs. While it is easy for ARDA farmers to acquire credit, this is more difficult for those on government schemes.

\_\_\_\_\_. "An Analysis of Economic and Institutional Factors Affecting Irrigation Development in Communal Lands of Zimbabwe." Ph.D. dissertation, University of Zimbabwe, 1984.

Discusses the irrigation policy in Zimbabwe with emphasis on small-holder irrigation schemes in the communal lands. Argues that schemes have been constructed with inadequate financial or economic consideration and documentation. Reveals lack of information, data, and analytical framework policy guidelines in small-holder irrigation development. Examines the institutions responsible for irrigation development--the Department of Rural Development (DERUDE), the Agricultural and Rural Development Authority (ARDA), and the Department of Agricultural, Technical, and Extension Services (AGRITEX). Describes in detail three case studies: Sanyati, Nyanyadzi, and Makonese. Observes that farmers on the schemes also cultivate food crops on separate rainfed blocks of land. Analyzes a farm income as affected by the size of irrigated and dryland production. Suggests that the increase in irrigation charges will affect farmers with smaller plots more adversely. Identifies a number of areas for further research at household, project, and national levels.

Stephens, T.F. "Water and Power Supplies for Small-Scale Irrigation in Mashonaland East." In African Regional Symposium on Small-Holder Irrigation, pp. 87-94. Edited by M.J. Blackie. Harare: University of Zimbabwe, Department of Land Management, 1984.

Overview of social and physical factors affecting small-scale irrigation development in the Mashonaland East Province. Examines in detail the more important general aspects of dams, weirs, wells and boreholes, and flow sources of irrigation. Briefly describes the factors to be considered in choosing a power supply for small-scale irrigation development, including electricity, diesel, petrol, wind, and sun as means of driving pumps.

Watermeyer, J.M. "An Outline of the History and Development of Irrigation in Zimbabwe." Development Magazine (April 1981):35-46.

Detailed description of irrigation methods and equipment developed in Zimbabwe over the last twenty years. Emphasizes the home-grown character of the irrigation machinery industry. Illustrates the activities of the national extension service and the Irrigation Association of Zimbabwe, which collect and distribute information on irrigation techniques. Discusses irrigation finance and calculations for the selection of irrigation pumps and pipes.

Weinrich, A.K.H. African Farmers in Rhodesia. London: Oxford University Press, 1975.

Based on research carried out in Rhodesia (now Zimbabwe) between 1962 and 1969, the book examines government policy and tests its effectiveness in light of the actual needs of peasant agriculture. Provides a sociological analysis of the three types of African agricultural settlements in Rhodesia (tribal lands, purchase areas, and irrigation schemes) and the ways in which economic and social factors are inextricably connected. Examines two irrigation schemes situated in different climatic regions and occupied by different tribal peoples.

Wild, R.M. "The Role of Water: Its Contribution to Rural Development." The Zimbabwe/Rhodesia Science News 14(1)(1980):15-17.

Discusses the eight objectives identified by the 1978 Integrated Plan for Rural Development of Zimbabwe Rhodesia: 1) development of large-scale irrigation; 2) agricultural land settlement through increasing water supply; 3) tribal trust land development; 4) urban development in tribal trust lands; 5) development of commercial agriculture; 6) urban development in existing centers; 7) development of tourism; 8) adequate training and motivation for irrigators. Stresses the interdependence of the objectives, especially the importance of the water supply.

Williams, O. "Irrigation Farming in the Southeast Lowveld of Zimbabwe: Retrospect and Prospect." Geography 66(3)(1981):228-232.

The author, who is with the University of Natal (South Africa), discusses the early development of irrigation and agriculture in the region together with data on more recent irrigation schemes at Mkwesine, Middle Sabi (for whites), and Chisumbanje (for blacks). Future large-scale developments in irrigation are envisaged within the context of the 1979 Integrated Plan for Rural Development.

## REPUBLIC OF SOUTH AFRICA

Bigg, D.C. "Weather Modification and Collection of Water From Mist." Public Works, Roads, and Transport (October 1971):19-30.

Examines various types of weather modification as a method of increasing water supply. Discusses the feasibility studies on precipitation augmentation in various parts of South Africa proposed by the Coordinated Committee for Hydrological Research. Discusses experiments already undertaken on mist precipitation, including the experimental mist-collection screen at Mariepskop (Eastern Transvaal). Recommends further research be carried out in this promising field.

Cass, A. "Irrigation Water Quality of Some Natal Rivers." Water S.A. 8(3)(1982):155-164.

The author, who is with the Department of Soil Science and Agrometeorology, Natal University; gives the results of an extensive study of irrigation-water quality of 43 sites in 29 rivers and 9 catchments in Natal. The article includes rainfall and evapotranspiration estimations, soil drainage, and management practices. The four variables were used to assess water quality. Water quality was assessed with respect to four chemical components.

Ciskei. Report of the Commission of Inquiry into the Economic Development of the Republic of Ciskei, Bisho, 1983.

Overview of the economic situation of the state. Among other things, the report discusses the land tenure position in major irrigation schemes. Underlines the need to combine the traditional system with the western system, preserving tribal decision-making procedures. Evaluates existing irrigation schemes and argues that the non-profitable schemes should be reorganized. Concludes that development of large-scale farming on a profitable basis should be pursued in the short term.

Cloete, G.S. and Human, J.J. "Cotton Production Under Irrigation and Different Cultivation Practices at Vaalharts and Upington." Agroplanta 12(2)(1980):17-22.

Presents the findings of the experiments carried out at the Vaalharts and Upington agricultural research stations in 1976-77. Seed cotton production, height of plants, leaf area index, and flowering of cotton were studied at different planting dates, irrigation levels, and intra-row spacing.

Daniel, J.B. McI. "Agricultural Development in the Ciskei: Review and Assessment." South African Geographical Journal 63(1)(1981).

Traces the development of two major irrigation schemes (at Keiskmmahoeck and Tyefu) and a recent rural settlement plan (at Zweledinga). The main criticisms of the agricultural development strategy concern the creation of an elite group of farmers, relative neglect of dryland farming, and the proposals to establish rural villages without specifying how they will mesh with the existing system of towns.



De Jager, J.M. and Mallett, J.B. "Effect of Moisture Stress Upon Maize Production and Its Economic Significance." South Africa Journal of Science 68(7)(1972):182-186.

A mathematical model for predicting the occurrence and number of days of moisture stress (the number of days that leaves wilt from lack of moisture) experienced by a maize crop during a growth season. Applies the model to three farming regions in Natal to calculate expected gross margins for each area over ten years. The model requires modification when used in different soil types. Argues that the advantages of this technique are that it allows the user to predict performance in new localities without running long-term experiments in the area and that it can assist farm planning with regard to fertilizer application and irrigation potential.

De Jager, J.M. "Planning and Scheduling Irrigation When Water Supply is Limiting." Crop Production 7(1978):173-176.

A mathematical model describing the interrelationship between irrigation, scheduling, climate, and soil for the wheat and maize crops. The model has been applied to decision-making at six stations in South Africa: Potchefstroom, Glen, Cedara, Bethlehem, Estcourt, and Newcastle. The author argues that the most important parameter for efficient irrigation control is the climate-irrigation effectivity (e), which reflects the increase in stress duration per unit increase in the selected soil-moisture depletion limit. Illustrates the results and concludes that irrigation water may be utilized more effectively in moist climates than in dry ones.

Gillooly, Jane F. and Mottram, J. "On the Estimation of Evapotranspiration of Maize Using Climatic Data." Crop Production 8(1979):13-18.

Estimates evapotranspiration for maize grown at Cedara Agricultural Research Institute using climatic data. The derived model is tested over different parts of the growing season; implications for irrigation scheduling are discussed.

Gillooly, Jane F. and Dyer, T.G.T. "Interactions Between Moisture Deficits, Maize Yields, and the Subtropical High-Pressure Belt over South Africa." Crop Production 9(1980):83-87.

Examines the linear relationship between values of a derived agroclimatic index, termed the moisture deficit, and positional changes in the subtropical high pressure belt. Discusses the interaction between maize yields in the major maize-producing area of South Africa and the mean position of the high pressure belt. Assesses the results of both these analyses in the light of monthly mean-pressure anomaly charts, which depict circulation conditions during contrasting wet and dry years. These preliminary results point to the possibility of developing a yield-forecasting scheme based on an index of the general atmospheric circulation over South Africa.

Godden, G.F., Nicol, S.M. and Venn, A.C. "Environmental Aspects of Rural Development with Particular Reference to the Keiskamma River Basin Study." Civil Engineer in South Africa 22(5)(1980):111-116.

Evaluates the potential impact on the environment of a dam on the Keiskamma River. Elements examined are: 1) the need for a water supply for two local industrial points, 2) the potential inundation of 400 ha of agricultural land, 3) the effects of the new irrigation scheme and possible further afforestation in the upstream catchment, 4) the effects of the dam runoff on irrigation withdrawals in the lower catchment, 5) the potential for new irrigation development downstream of the dam.

Grant, R.F. and Lea, J.D. "Drought-Resistance Selection Criteria for Agricultural Crops." Crop Production 11(1982):13-20.

Discusses current approaches to reduction of yield loss under suboptimal moisture regimes. Although most breeding and evaluation programs rely largely on empirical observation under various climatic conditions, recent research developments indicate the possibility of establishing a genetic basis for drought-resistance improvement. This would allow more accurate characterization of drought-resistant properties and their heritability. Hybridization could then be more deliberately planned for optimization of resistance and subsequent selection could occur on the basis of measured parameters. Efficiency of breeding drought resistance could thus be greatly enhanced.

Heeg, J., Breen, C.M. and Roger, K.H. "The Pongolo Floodplain: A Unique Ecosystem Threatened." Civil Engineer in South Africa 22(5)(1980):125-128.

The article, produced as a result of the research activities at Natal University, South Africa; discusses the hydrological effects of the Pongolapoort Dam on the Pongolo floodplain. The authors estimate annual water requirements to maintain the floodplain pans at the maximum retention level for a reasonable period of time. This can be met with a 67 percent saving on the natural flow through the system.

Hensley, M. "Brack: A Threat to Our Irrigation Schemes." South Africa Journal of Science 66(6)(1970):180-181.

Discusses saline soils and irrigation planning in South Africa. Argues that research needs include a brack survey of existing irrigation schemes and an intensive study of all aspects of water movement in soils. Detailed soil classification tailored (probably at the phase level) to meet practical requirements is a prerequisite for the latter study. The information gathered should be used to predict the long-term results of irrigation on each soil type, on each scheme, and the predictions integrated into the planning of the scheme. Once irrigation has begun, soil-water-brack conditions should be carefully studied in order to feed back information for improving predictions and planning subsequent stages of development on the same and other irrigation schemes.

Hensley, M. and Laker, M.C. "A Proposed Integrated Procedure for the Identification, Delineation, Evaluation, and Planning of Irrigable Land." In Proceedings of the Ninth National Congress of the Soil Science Society of Southern Africa, pp. 15-22. Durban, South Africa: Department of Agriculture and Fisheries, Technical Communication No. 174, 1981.

Presents a simple step-by-step guideline with the objective of serving interdisciplinary identification, delineation, evaluation, and planning of irrigable land. Emphasis is placed on the major roles which experts in fields such as crop science and economics should play during the initial phases of soil-resource inventories, especially in the definition of mapping units for basic soil maps. Stresses the importance of interdisciplinary cooperation during the final interpretation and resource-allocation (planning) stages.

Jupp, P.G., McIntosh, B.M. and Nevill, E.M. "A Survey of the Mosquito and Culicoides Faunas at Two Localities in the Karoo Region of South Africa, With Some Observations on Bionomics." Onderstepoort Journal of Veterinary Research 47(1)(1980):1-6.

The author, who is with the Arbovirus Unit of the National Institute for Virology in Johannesburg, reports on a survey about the occurrence of 23 species of mosquitoes and culicoides in areas where dams and irrigation works were constructed. The survey was conducted at Bethulie and Luckhoff, in the arid Karoo region of the southern Orange Free State.

Kockemoer, W. "Successful Micro-Irrigation in Zululand, Llanwarne Estates, Zululand." The Citrus and Subtropical Fruit Journal 549(1979):14-15.

Discusses the advantages of micro-irrigation systems in the cultivation of trees. After the first system was installed, in 1974, water and labor savings were made, new plantings came into production sooner, and larger production was recorded. Other advantages include: erosion prevention, performance of other orchard activities as spraying, fertilizing, picking, facilitated weed control. The method is independent of soil structure or ground grade.

Kruger, F.J., Van der Zel, D.W. and Andrag, R.H. "S.O.S. for Mountain Catchments." Ekos 1(1)(1980):18-21.

The author, who is with the Forestry Research Institute in Pretoria, stresses the economic importance of South Africa's mountain catchments. They occupy about 8 percent of the land surface but yield 49 percent of the country's total annual runoff. Examines the Department of Forestry's mountain catchments management, including the afforestation permit system. Discusses the research program of the Jonkershoek hydrological research complex in catchment conservation. Research is in the fields of hydrology and ecology, and on recreational use.

Legge, W.C.S. "Design Technique Development for Dams in South Africa." Aqua 2(1982):378-380.

The author, who is with the Department of Environmental Affairs, South Africa; discusses improvements in techniques and design of arch dams over the past 80 years, especially since World War II.

McGee, O. "The Transport of Water Vapor in the Atmosphere Over Southern Africa." South African Geographical Journal 57(2)(1975):135-147.

A regional study of the transport of water vapor over South Africa. Such studies may provide the basis for exploitation of atmospheric water resources (see alternative and/or supplemental to irrigation) through artificial augmentation of precipitation and repression of evaporation. Concludes that the results match with similar studies' outcomes in other regions of the globe.

Middleton, B.J., Pitman, W.V., Midgley, D.C., Lorentz, S.A., Robertson, R.M. and Potgieter, D.J. Surface Water Resources of South Africa. University of the Witwatersrand, Hydrological Research Unit, Reports 8-13, 1981.

Final report of the research project on water resources in South Africa carried out by the Hydrological Research Unit of the University of Witwatersrand for the Water Research Commission. The six volumes contain systematic hydrological information and estimates of water resources. The series provides methods whereby hydrologists can generate the streamflow history, predict stream behavior, and analyze the interplay of complex water supply and demand systems. A user's guide to the series is now being prepared.

Midgley, D.C. "Water in the Service of Man." South Africa Journal of Science 66(12)(1970):350-358.

Address to the March 1968 symposium organized by the Public Programs Committee of the South Africa Association for the Advancement of Science. Discusses the availability of water in South Africa, the growth of water demands and the planning problems involved in the harnessing of water in the service of man.

\_\_\_\_\_. "Hydrological Research in Southern Africa." South Africa Journal of Science 66(12)(1970).

Reviews significant work in surface and ground water hydrology throughout the African sub-continent. Focuses on engineering hydrology. Argues that until a decade ago data collection and limited research was undertaken largely by government agencies. Despite the vital importance of water in most parts of Southern Africa, universities, with the exception of the Witwatersrand and Natal, have undertaken little hydrological research. Concludes by advocating co-ordination of data collection and expansion of the present observation services from a concentration on a few localized, small-scale, highly-instrumented hydrological research stations.

Murray, D.L. and Gorgens, A.H.M. "Storm Runoff Analysis on Three Semiarid Catchments." Water S.A. 7(4)(1981):223-233.

Findings of a statistical analysis of storm rainfall and stream-flow data from three semiarid catchments in the Ecca River region. The purpose of the study is to predict storm flow volumes from a number of independent variables. The author found that the best index of catchment wetness at the beginning of a storm was generally the seven-day antecedent rainfall.

Plessis, H.M. du. "Suitability of Dam Waters in South Africa for Irrigation as Deduced from Historical Data." Proceedings of the Ninth National Congress of the Soil Science Society of Southern Africa, pp. 23-30. Durban, South Africa: Department of Agriculture and Fisheries, Technical Communication No. 174, 1981.

Presents the results of chemical analysis of water samples from storage dams in South Africa carried out at the Soil and Irrigation Research Institute between 1958 and 1972. Evaluates the suitability of the sampled water sources for irrigation. Dams situated in the Vaal and Limpopo River catchments generally had a lower sodium and salinity hazard for irrigation than those in the rest of the country. This analysis of dam waters indicates that, in general, South Africa has water of good quality for irrigation. The extent to which this picture has changed as a result of increasing industrialization and re-use of water since the data were obtained can be determined by analyzing new samples.

Republic of South Africa. Water Research Commission. Annual Report(s), 1971-1982. Pretoria.

The Water Research Commission (WRC) was established in 1971 by the Water Research Act (Act No. 34 of 1971) to make provision for the promotion of research with regard to water matters. Its objectives are "to coordinate, to promote, to encourage research with respect to the occurrence, preservation, conservation, utilization, control, supply, distribution, purification, pollution or reclamation of water supply and water . . . with respect to agricultural, industrial and urban purposes." Since 1971 a number of publications have resulted from research financed wholly or partially by the Commission; the annual reports for 1981 and 1982 include a cumulative listing of these publications. The annual reports since 1973 provide detailed information on the following activities: 1) projects completed, 2) ongoing research, 3) future planning and programming of water research/development in the following areas: water reclamation, ground water, water environment, treatment of municipal wastewater, industrial elements, desalination, surface hydrology, and rainfall simulations. The South African Information Center is operated as an independent unit on behalf of the Commission and provides information services in water and related fields. A computerized data base, "Waterlit," has been developed by the Center. The data base contained more than 60,000 publications in 1982. The Center currently operates approximately 200 "selective dissemination of information" profiles and does some 60 information searches each month. The current research emphasis is on rainfall simulation, irrigation, industrial effluents, and municipal water waste. The Commission started primary research on irrigation in 1975.

\_\_\_\_\_. Department of Agricultural Technical Services. "Survey of Quality of Irrigation Water in the Natal Region, 1972-1977," by A. Cass. In Agricultural Research 1978, pp. 102-104. Pretoria: 1978.

A survey of the chemical composition of Natal's rivers to assess the quality of irrigation water in the region. Sites selected for analysis were confined to headwaters of important irrigation water sources or near important or potentially important irrigation areas in the interior of Natal. A simple model was proposed which allowed soil salinity and sodicity to be calculated for poorly drained alkaline soils from irrigation water characteristics, rainfall, evapotranspiration, and management factors. The survey showed that the majority of the larger rivers, especially in central and southern Natal, have good irrigation water. Some of the larger rivers (Pongola and Mkuzi) in northern Natal are of poorer quality. Indiscriminate irrigation in these catchments should be avoided. Many of Natal's smaller rivers are also of poor quality; this may have important consequences for smaller irrigation enterprises. The survey did not include irrigation water from sources to the Natal coast.

\_\_\_\_\_. Department of Agriculture and Fisheries, Soil and Irrigation Research Institute. The Role of the Ammonium Ion in Aiding the Disposal of Alkaline Sodium-Rich Effluents by Irrigation, by J.G. Thompson. Technical Communication No. 183. Pretoria: 1983.

Report of a study conducted in South Africa on the role of the ammonium ion in lowering the soil's sodium absorption characteristics. Five widely different soils were treated under controlled laboratory conditions, first with an effluent that contained no ammonium salts and then with the same effluent to which a small amount of an ammonium salt had been added. Re-analysis of the treated soils showed clearly that in all instances the ammonium ion kept an appreciable amount of sodium off the exchange complex.

Soil Science Society of Southern Africa. Proceedings of the Ninth National Congress. Durban, South Africa: Department of Agriculture and Fisheries, Technical Communication No. 174, 1980.

The Soil Science Society formed part of a combined congress with the South African Society of Crop Production. The 22 submitted papers deal with soil physics, irrigation planning, soil-water relationships, soil fertility, soil chemistry, pedology, and land use. Ten summaries of submitted papers which were not intended for publication are also reproduced.

Stallbrass, J.L. "Regional Water Resources Planning in South Africa." South Africa Journal of Science 67(3)(1971):159-177.

Stresses the need for water resources planning in South Africa. Underscores the advantages of regional water resources planning because it provides a blueprint to enable water development to proceed systematically, thus avoiding the construction of new projects on an ad hoc basis.

Stephenson, David. "Integration Development of the Orange-Vaal and Tugela Basins." South Africa Journal of Science 67(9)(1971):457-463.

Examines the total water demand in the Witwatersrand area as covered by the Vaal Dam, the Upper Tugela, the Oxbow area, the Caledon schemes. Identifies various benefits stemming from water resource development in the region, such as recycling for irrigation water that has been used to generate hydroelectric power and recreational use of lakes created by dams. Examines the optimum distribution of water resources of the Orange-Vaal and Tugela basins, with a view to minimizing total costs of conduits, supply, and storage.

Streutker, A. "Moisture Profiles and Salination of Soils Under Drip Irrigation in the Republic of South Africa." In Proceedings of the 2nd International Drip Irrigation Congress, San Diego, California, July 7-14, 1974. Riverside: The Congress. 1974.

Report of a study which sought to establish criteria for both planning and managing drip systems. Soil moisture profiles and soil moisture movement were studied under several combinations of drip intensity, spacing between drippers, and irrigation period and frequency. Three different sites in the summer rainfall area (east coast) were studied: Barkey West, Zedediele and Groblersdel, (little salt accumulation was increased) under drip systems during the period of investigation. Concludes by giving some values of water usage and crop yield of cotton, potatoes, and tomatoes.

\_\_\_\_\_. "Irrigation, Crop Yield and Drainage at the Vaalharts Irrigation Scheme: 1. The Contribution of Farm Water Usage, Irrigation Management, and Leakage from the Canal System to Waterlogging." Water S.A. 7(2)(1981):97-106.

A report on experimental research to improve irrigation efficiency and reduce leaching losses of fertilizer and water leakage from a canal system in the Vaalharts scheme. Waterlogging and salinization were identified as problems.

\_\_\_\_\_. "Irrigation, Crop Yield and Drainage at the Vaalharts Irrigation Scheme: 3. The Influence of Salination Above a Shallow Ground-Water Table on the Yield of Wheat and Other Crops." Water S.A. 7(4)(1981):255-64.

The paper discusses the fact that overirrigation and leakage from soil dams produced a shallow ground-water table at the Vaalharts Irrigation Scheme. Analyzes soil characteristics and concludes that the major reasons for the reduced yield of wheat, cotton, and groundnuts in the area during the 1974-1976 period were sodium absorption ratio, high bulk density, and high soil-moisture content. These factors were also due to overirrigation and leakage from soil dams.

Van Rooyen C.J. "The Availability of Water and Labor as Variable Resources in Planning for Optimum Organization in Irrigation Farming." Agrekon 18(1)(1979):9-17.

Based on a doctoral thesis (University of Pretoria, 1973) about the application of linear programming methods to the problem of optimal farming organization in the Hartberspoort Dam irrigation scheme. The author argues that variable resource programming offers possibilities for both short- and long-term planning on the farm and at the national level.

Vetger, J.R. "Ground Water in South Africa." Farming in South Africa 5(1970):35-38.

The author discusses the need to develop national use of underground water in the various regions of South Africa. Recharge, runoff and soil-conditions data are examined. The article underlines the importance of performing accurate yield tests on boreholes before equipping the hole for irrigation.

Villiers, A. de. "A New Approach for the Planning and Development of Small-Holder Irrigation Schemes in the Black States of South Africa." Agrekon 17(4)(1978):8-13.

Experience in Swaziland has proved that small-holder irrigation schemes can be successfully developed by the application of an integrated development framework.

Vink, N. and Kassier, W.E. "A Paradigm for a Micro-Level Rural Development Strategy." The South African Journal of Economics 52(2)(1983):283-296.

The objective of the article is to improve food production on an existing small-scale development project through increasing the allocative and technical efficiency of both the individual farmer and the system.

Wellington, John H. "The Water Problem." In Southwest Africa and Its Human Issues. Oxford: Clarendon Press, 1967.

Examines problems of availability of water in Southwest Africa. Describes the course of the main sources of water (the Orange, Kunene, and Okavango rivers), which are used for irrigation only in the southern and northern marginal areas. Attempts an appraisal of the value of surface and ground water to the territory.

Wessels, W.P.J. "Irrigation Water...Efficient Application." Farming in South Africa 45(1970):49-59.

This article is intended as a guide for the South African farmer when he has to make decisions about the planning, construction, and management of irrigation systems.



Wieht, C.L. "The Influence of Vegetation in South African Mountain Catchments on Water Supplies." South Africa Journal of Science 67(3)(1971):201-217.

Divides surface water resources in two main categories: highly secure applies and non-secure supplies. Discusses a method for determining hydro-economic optimum management of storage in a given system. The results of the hydro-economic analysis can reveal at what stage and to what extent water reclamation, recycling within the system, desalination of effluents, importation from neighboring catchments, or other measures for increasing highly secure water supplies are more economic than adding storage. For the rivers of the interior plateau, the highly secure component of yield cannot usually be greatly enhanced by increasing the storage provision beyond a relatively small proportion of mean riverflow. Increased storage should therefore be provided only if needed for purposes of meeting increased low-guarantee water demands. High-guarantee demands should be satisfied by importation, recycling of reclaimed water, abstraction from periodically recharged groundwater, or other measures and to the extent that is economically feasible rather than by increased storage of runoff from the same system.

Wynand, J. Vys. "Some Results of the Field Survey of Drip-Irrigation Systems in the Republic of South Africa." In Proceedings of the 2nd International Drip Irrigation Congress, San Diego, California, July 7-14, 1974. Riverside: The Congress, 1974.

Report of an extensive survey conducted in the Republic of South Africa in 1973 on existing drip irrigation systems under a variety of climatic, soil, crop, and management conditions. Two-thirds of drip irrigation systems are located in the southwestern coastal area with a winter rainfall. A fifth of the drip-irrigated land is in the northern and eastern Transvaal. Only a few systems are in operation in the east coast area. The purpose of the survey was to evaluate engineering aspects of drip irrigation systems under practical farming conditions and identify specific problems of design, operation, and management to be investigated in future research programs. The report concludes that, even if most systems operate satisfactorily, further reduction in capital and annual cost is possible through careful design and purchase. An inexpensive method to monitor soil moisture effectively under farming conditions is needed.

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