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TOO MUCH OR TOO LITTLE WATER: RESEARCH DEDICATION AND LESSONS FOR NEW GENERATION AGRICULTURAL ECONOMISTS

MF Viljoen[1]

1. INTRODUCTION

With the development of visual news, people today are much more aware than before of a whole array of disasters occurring all over the globe. Viewing video footage of a disaster happening, whether it is man-made such as the collapse of the twin towers in New York, or natural such as the Mozambique floods, the event becomes a reality on TV screens. Viewers can relate with emotion to the disaster and questions such as the following may come to the fore:

- What caused the disaster?
- What will be the extent of the total damages and disruption?
- What is the probability of a similar disaster happening in the future?
- What can be done to prevent or minimise the disruption and damages, should such a disaster recur?

In order to provide credible answers to these types of questions, scientific research is required. This has been the main focus of the research I have been involved in during my career.

More specifically, the research centred on the determination and management of the economic impacts of too much and too little water; or stated otherwise,

[1] *Professor, Department of Agricultural Economics, University of the Free State, Bloemfontein.*

the determination and management of the impacts of two kinds of water disasters, namely floods and droughts. The research was executed over a quarter of a century in different phases, with each phase triggered by extreme climatic events in the interior of the country.

A first phase of flood impact research started in 1975 after abnormally high rainfall during 1974 over large parts of South Africa, and continued until the early eighties. This was followed by a research phase about the economic implications of water restrictions during the rest of the eighties due to abnormally low rainfall in various parts of the country and the imposition of water restrictions during the period 1983 - 1987. Extensive flooding in the central interior in 1988 triggered the second phase of flood impact research, which was largely conducted over the nineties.

An overview of the research conducted during the different phases is presented next in order to trace the learning curve and to put the lessons learned with regard to research approach, methodology and requirements into context.

2. PHASE 1: THE EX-POST FLOOD DAMAGE RESEARCH PHASE (1975 - 1982)

The first focused scientific research regarding flood damage assessment in South Africa commenced in 1975 after extensive flooding in the interior of the country during 1974.

The Water Research Commission was requested by the Department of Water Affairs to finance a research project to scientifically determine the nature and extent of the damages caused by the 1974 flood. The Institute for Social and Economic Research (ISER) of the University of the Orange Free State and the Bureau of Economic Research (BER) of the University of Stellenbosch were appointed for this joint research effort. Specific aims of this ex-post research phase were (Viljoen *et al.*, 1978):

- To develop a methodology for identification and assessment of all types of flood damages;
- To apply the methodology in different river reaches in order to determine flood damages;
- To describe the circumstances of each damage so that a logical relationship between physical damage and flood circumstances could be established for the development of a paradigm;

- To formulate the paradigm to supply guidelines for application in other rivers.

This phase was completed during the beginning of the eighties and was a necessary point of departure (as was the case with flood damage research in other countries) for follow-up research that had to wait until the 1990s. One of the publications from this research titled "*Guidelines for assessing flood damage in South Africa*" (Smith *et al*., 1981) summarised the research experience gained during this phase by providing guidelines for future research.

Of this research phase, the following characteristics should be noted:

- The fundamental premise for determining damage was anthropocentric (flood effects were regarded as damage when the community suffered losses);

- The main emphasis was on determining direct tangible damage while the intangible damage was only described partially;

- The relationships between physical damage and flood circumstances were depicted by loss functions. The motivation for developing loss functions was that they are necessary building blocks in the traditional approach to determine an optimal set of flood control/mitigation measures for a flood area; the traditional approach refers to the benefit-cost analytical framework.

The data obtained during the *ex-post* phase were not sufficient to construct a complete set of loss functions needed for flood control planning. It was, in fact, possible to determine loss functions only for a few land-use types (Viljoen *et al*., 1984). There was, therefore, a recommendation to supplement and/or follow the *ex-post* phase by *ex-ante* research. *Ex-ante* research would render it possible to construct loss functions without floods actually occurring. This would also allow for a complete set of loss functions as well as flood damage management aids to be developed. This research, however necessary, had to wait until a later date to be executed as a result of the droughts in the interior of the country during the eighties.

3. PHASE 2: THE SOCIO-ECONOMIC IMPACTS OF WATER RESTRICTIONS (1983 – 1990)

Extensive droughts in the interior of the country from 1983 led to the imposition of water restrictions on various sectors and water supply systems.

The Water Research Commission requested three institutions to research the nature and extent of the socio-economic and financial consequences of water restrictions. The institutions were ISER of the University of the Orange Free State, the Bureau of Market Research of the University of South Africa and the Centre for Applied Social Research of the University of Natal. Each institution was requested to conduct research over the total study region, comprising the Ngagane River Government Water Scheme, the Umgeni Catchment Area, the Riet River Government Water Scheme, the Vaalharts Government Water Scheme and the Vaal River System, but to work on specific sectors (Van Zyl & Viljoen, 1987).

ISER focused on irrigation farming, mining, electricity supply and central government. As it was the first time that scientific research about the effects of water restrictions was conducted in South Africa, it was necessary to first develop a methodology for this purpose. The methodology developed encompassed a reformulation and adaptation of the methodology used during the previous flood damage research phase for application in a water shortage situation.

After completion of the first research phase and publishing of research reports by the three research institutions (Martins, 1986; Van Zyl & Viljoen, 1987; Schlemmer *et al.*, 1989) ISER was requested to compile a summary report (Van Zyl & Viljoen, 1987), of the findings of the three institutions for the period 1983 to 1985 and to determine the total financial impacts over the total restriction period (1983 – 1987) for the Vaal River and Riet River water supply schemes.

Besides determining the direct tangible losses for the Vaal River the indirect tangible losses also had to be assessed by using the input-output analytical technique. With this technique it was possible to determine the total extent of the financial impact of water restrictions for different economic sectors and it was, for instance, calculated that the induced effects were twice as high as the direct effects. Average unit values of water for different sectors of the economy were also determined, which is useful when decisions on water restriction intensities for different sectors need to be made (Botha & Viljoen, 1991).

The loss function concept used during the flood damage research phase was adapted to be applicable on different types of irrigation farms in the Vaalharts irrigation area. Loss functions, which in this case described the relationship between varying levels of water restrictions and the financial effects on typical farms, were established by developing dynamic linear programming (DLP) models for different typical farming units and simulating the impact of different levels of water restrictions on the financial results of typical farms (Viljoen *et al.*, 1992). Besides compiling loss functions for typical farms, loss functions were also developed for the total Vaalharts irrigation area to show both the direct and indirect consequences of different levels of water restrictions.

These loss functions made it possible to assess the effects of different intensities of water restrictions on the financial survival of different typical farming units as well as the impact on the total Vaalharts irrigation sector. With this information better decisions could be made on how future water restrictions in the Vaalharts irrigation area should be managed to minimise the negative impact on irrigation farming.

This research was a necessary departure for management of water restriction situations and it was suggested that further research was needed to refine the loss functions and to relate them to specific water restriction measures, also for other economic sectors and regions.

4. PHASE 3: THE EX-ANTE FLOOD DAMAGE RESEARCH PHASE (1991 – 2001)

After extensive flooding in 1988 and a request to revise the national flood disaster policy for South Africa, the WRC provided funds to the Department of Agricultural Economics at the University of the Free State to start the *ex-ante* research phase mentioned above. This phase, which can be subdivided into four sub-phases, started with the same basic premises of the *ex-post* phase as its point of departure (anthropocentric, focus on direct damage, loss functions needed for optimal flood control planning in cost-benefit framework).

The aims of the first sub-phase (1991 - 1994) were (Viljoen *et al.*, 1996):

- To develop loss functions to determine potential damage for different land use types in demarcated flood plains.
- To develop the outline of a computer database in which the loss functions could be stored and applied to the research area.
- To develop a computer programme to determine the benefits of different combinations of flood control measures with the loss functions in the database.

- To demonstrate the application of the computer programme for flood management planning in the research area.

During this sub-phase it was possible to develop a complete set of loss functions for the research area (Upington on the Orange River and Vereeniging on the Vaal River), and to develop computer programmes to determine optimum combinations of flood control measures. A computer simulation programme, called FLODSIM was developed for the irrigation area (Du Plessis & Viljoen, 1996), and another, called ANUFLOOD (developed by the Centre for Resource and Environmental Studies at the Australian National University in Canberra) was adapted in co-operation with Australian researchers for urban areas in South Africa (Booysen & Viljoen, 1996).

Sub-phase 2 (1995 - 1997) was necessary to overcome shortcomings of the results of sub-phase 1, i.e. the location specificity of computer programmes and loss functions. The research area was expanded to include the Mfolozi sugar cane production area in KwaZulu-Natal, the Uitenhage and Despatch formal urban areas along the Swartkops River in the Eastern Cape, and the Soweto on Sea informal urban area along the Chatty River, also in the Eastern Cape. The specific aims were (Du Plessis *et al.*, 1999):

- Development of flood damage functions for alternative land use types in floodplains in irrigation and urban areas of South Africa.

- Further development of flood damage models and computer programmes to be more generally applicable in irrigation and urban areas. Besides the utilisation of new technology like remote sensing, the models should also be adapted to be applicable at three levels of decision-making, namely local, provincial and national level and should also be in accordance with the revised national flood management policy

- To test, validate and verify the models and computer programmes in selected areas.

Generalised computer programmes (FLODSIM and TEWA; the latter a GIS programme utilising the same information as ANUFLOOD) and standardised loss functions resulted from this research (Du Plessis *et al.*, 1999; Booysen & Viljoen, 1999). It has now become possible to apply them as flood control planning and management tools in different flood plains in South Africa. In order to maximise the benefits of their use, the recommendation was made to apply them as part of a holistic approach to integrated hydrological catchment management.

Sub-phase 3 (1998 - 1999) was conducted with this in mind. This phase aimed mainly at the refinement of the computer programmes, loss functions and questionnaires and dissemination thereof as flood management aids to all interested parties and role-players involved in flood plain and flood control planning in South Africa. Besides applying and testing FLODSIM and TEWA in actual case studies along the Orange and Swartkops Rivers and development of FLODCAL (a computer based questionnaire), a sociological study was conducted to determine the suitability of the approach in assessing acceptable flood control mitigation measures for a developing local community. The Community Agency for Social Enquiry (CASE) was co-opted to research the flood-affected community of Pietermaritzburg, which experienced the 1995 Christmas Day flood.

This research indicated that a number of changes were needed in the adopted approach. Concerning the premises of the approach the following were suggested (Viljoen *et al.*, 2001):

- The focus on the direct tangible damage (which uses the monetary value of damage as a yardstick) must be changed. Instead of simply assessing the value and extent of losses in monetary terms, a relative impact index should be calculated by weighing monetary losses by either household incomes or the value of household possessions. This index will be more reflective of actual damage and should also capture some of the intangible damage.

- The cost benefit technique, which typically uses one criterion (economic efficiency), does not effectively incorporate other concerns. These include distributional issues, social and environmental impacts, and a wider range of stakeholders. Multiple criteria decision analysis (MCDA), with wide participation of all concerned, is suggested. In the MCDA approach the focus is on finding satisfactory alternatives that are acceptable across a number of objectives as opposed to optimal solutions that deal with single objective functions.

- The anthropocentric basis of identifying and quantifying the effects of floods must broaden so that the sociological and natural environmental dimension also receives proper attention. This will add substantially to determining socially acceptable and environmentally friendly flood management options within a wider (more holistic) disaster management and developmental approach.

Sub-phase 4, which commenced during 2000, focussed on technology transfer and disaster management training. After the 1994 national elections a process was set in motion to develop a new Disaster Management Act for South Africa. This Act, which also incorporates the National Flood Management Policy, is expected to pass through parliament later in 2002. Where the focus in the past had been on reactive disaster management, the new Act will require continuous management and emphasizes pro-active management. It also requires new structures to be established and charges local authorities with the responsibility of putting in place pro-active disaster management plans that will allow them to deal with all types of disasters (man-made and natural).

Awareness of these new requirements resulted in the launch of a focused technology transfer action to inform stakeholders in the public and private sector involved in flood management of the flood management aids (FLODSIM, TEWA and FLODCAL) developed during the research and to demonstrate how they can be used in pro-active flood management. A decision was also taken to start a disaster management training programme for disaster managers. This is one of the main activities of DiMTEC (Disaster Management Training and Education Centre for Africa), which started this year within the Department of Agricultural Economics at the University of the Free State.

5. LESSONS LEARNED

From participating in this research programme, the following lessons with regard to research approach, methodology and requirements were learned:

i) **Training needs**
Broad based training but with sufficient specialisation in Economics and Mathematical Statistics, besides Agricultural Economics, is required to make the Agricultural Economist an effective researcher and for successful participation in multi-disciplinary practice orientated research programmes.

ii) **Academic and institutional support**
Integrating and/or collaborating with a strong academic department, research institute and/or research team with expertise in conducting research and rendering research leadership as well as the availability of good research infrastructure is most beneficial to develop as a researcher and to provide good quality research products.

iii) **Research theme**

Research programmes are expensive and need funding over a period of time, therefore a research theme should be worked on for which sufficient funding is available. The Water Research Commission provided sufficient funding for this programme. These days strong competition for funding makes it necessary to explore international sources as well. The research theme must thus be of international significance.

iv) **Specialisation**

To gain research depth, specialisation and dedication is required over a substantial period of time. This research programme specialises on only one resource, namely water, with the research theme further delimited to focus only on the impacts and management of too much and too little water.

v) **Continuous learning**

In-depth research requires a process of continuous learning as was experienced with this programme. Even when the flood research was put on hold during the eighties, the learning curve continued by adapting the flood damage methodology to determine the impacts of water restrictions and by applying new techniques like input-output analysis and simulation with DLP-models.

vi) **Methodology**

In-depth research further requires that basic and applied research be merged and that deductive logic as well as inductive reasoning be applied. During all the research phases the impacts of real events first had to be investigated before decision aids could be developed. Applied research thus followed on basic research. Deductive logic is for instance demonstrated where premises were used to identify and measure impacts and inductive reasoning where premises were established or adapted based on empirical research.

vii) **Multi-disciplinary**

Providing research products that are useful in practice required multi-disciplinary team research, collaboration with academics from other universities in South Africa and abroad as well as with scientists and researchers from various organizations and institutions. The demand for multi-disciplinary research increased over time as research progress was made and will become even more important in future. Mono-disciplinary research becomes increasingly less relevant.

viii) **Time and phases**
The development of the flood damage management aids (FLODSIM, TEWA and FLODCAL) required a lot of time and various research phases to be finalized for practical application. They are at present sufficiently developed to be applied for continuous disaster management according to the requirements of the new Disaster Management Act.

ix) **Technology transfer**
Technology transfer must be seen as a necessary component of a complete research approach. Demonstration of the usefulness of flood damage management aids in practical applications largely contributed to their acceptance in practice.

x) **Problem solving capability**
Practical applicability of research products depends on their capability within programmes to solve or to manage real problems. The new approach to disaster management can be summarized as holistic, integrated and continuous. Within this approach the developed flood damage management aids have meaningful application.

xi) **Educational value**
Practical applicability of research products is further highlighted when they find application within education programmes. Education on comprehensive disaster management was feasible after the expertise and knowledge obtained in the development of the decision aids to manage water disasters was merged with the requirements for pro-active disaster management of the new Disaster Management Act. This development is a first for South Africa and opens a totally new research field with great opportunities for DiMTEC.

xii) **Ongoing process**
Research is by its nature a cyclical expanding spiral. Answers to research questions create new questions, requiring further research. For instance the disaster management aids must be maintained by a process of continuous research and be expanded further to comprehensively accommodate the sociological and natural environmental dimensions of disasters for application within a holistic, integrated and continuous disaster management approach.

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