The value of rain

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ABSTRACT

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While the GWP definition of Integrated Water Resources Management (IWRM) refers to 'co-ordinated development and management of *water, land and related resources*', it still reflects the traditional focus of the water resources sector on the liquid water part (surface and groundwater) of the hydrological cycle. Once we consider the land as a processor of rainfall, with fresh water resources as one of its outputs, we are more ready to accept the view that ecosystems are providers of fresh water resources, rather than a new sector that is competing for water with the traditional water using sectors.
Today's *land use* is the result of past decisions, made by many individual landowners who mainly considered the productivity of the *land*, *not water*. Even the investment decisions for public irrigation systems were largely based on the *return on capital*, not on the return on the water resources. It seems justified, therefore, to expect that in almost all catchments the value that is generated from the rain can be increased substantially, by adapting current land use and agricultural water allocations.

Keywords: water valuation, land, water, ecosystems, irrigation, rainfall, hydrology, economics, virtual reservoirs, virtuous dams.

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Summary

Rainfall is the source of all water resources. Yet, it is hardly considered as such in the scientific literature on water valuation. This paper explores the gains that can be made by shifting the focus of water resources management from the water towards the rain. This also causes a shift in our perception of what is the largest user of water: instead of irrigation it is the *evapotranspiration.* Once we appreciate this, it also becomes clear that land use is a major determinant of the total value generated by the rainfall in a given catchment. Today's *land use* is the result of past decisions, made by many individual landowners who mainly considered the productivity of the *land*, *not water*. Even the investment decisions for public irrigation systems were largely based on the *return on capital*, not on the return on the water resources. It seems justified, therefore, to expect that in almost all catchments the value that is generated from the rain can be increased substantially by adapting current land use and water allocations. The recognition of the rainfall processing functions of the terrestrial ecosystems would therefore be more appropriately reflected by calling this new approach: *Land, Water and Ecosystems Management* (LWEM).

Variability of flow in rivers and streams is less than rainfall variability, due to the buffering effect of the terrestrial ecosystems. Water resources engineers construct dams and reservoirs to reduce this variability even further, in order to be able to meet the demand for water. With LWEM, there will be greater emphasis on dealing with *uncertainty of rainfall*, e.g. by seeking opportunities for increasing the buffering capacity of the terrestrial ecosystems, by increasing infiltration and retention of rainfall in the soil. These natural water reserves in the landscape may be conceived of as *virtuous dams*.

Irrigation, also, is a way of coping with uncertainty of rainfall. In LWEM, irrigation is considered as an insurance against uncertainty of rainfall, for which farmers must expect to pay an insurance premium. Since the irrigation water supplying agency also depends on rainfall, it will not always be possible to supply farmers' irrigation demand. An important element of LWEM will be a negotiated contract between farmers and the irrigation water supplying agency, which – like in an insurance policy – specifies the extent of security offered. For a farmer, this contract provides a level of security against erratic rainfall that could also be derived from a storage reservoir on his land; the contract, therefore, may be conceived of as a *virtual reservoir*.

Preface

The Netherlands Government and FAO jointly organized an International Conference on Water for Food and Ecosystems (WFE), held in The Hague from 31 January to 5 February 2005. The focus was on promoting sustainable management of water, based on a stakeholder-centred approach that facilitates sound, efficient and equitable decision making in the assessment, allocation and regulation of water resources, in terms of both quantity and quality.
(**http://www.fao.org/ag/wfe2005/conference_en.htm**)
One of the themes of the Conference was *A "New Economy" for Water for Food and Ecosystems*. According to the synthesis paper for this theme: 'The challenge is to move towards a mechanism to share and expand the "pie" of water related benefits. ….. The basis for a *new economy* for water for food and ecosystems would be that water is managed in a way that reflects its value.' (Hermans & Hellegers, 2005)

In a follow-up document of the WFE Conference, Hermans *et al.* (2005) state that 'so far, water valuation has been mainly the domain of economists who express the value of water in monetary terms.' The authors make a case for a stakeholder approach to water valuation, which is more than 'a means of putting a monetary value on water resources, but rather a structured and transparent mechanism to help stakeholders express the values that water related goods and services represent to them.'

This report (re)examines the practices used for valuation, allocation and use of water in the context of water for food and ecosystems.

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Front cover: Part of watercolour by H.J. Weissenbruch (1824-1903). Courtesy Simonis & Buunk, Ede.

1 Rainfall: the source

"Nowadays people know the price of everything and the value of nothing."
Oscar Wilde, 1854-1900. Anglo-Irish dramatist and wit

Rainfall, of course, is the source of all water resources. Yet, it is hardly considered as such in the scientific literature on water valuation, maybe because *source* is commonly taken to be water *rising* from the ground (see Box), so that even though *source* also means the *origin* of something, people may find it hard to relate that origin to a *falling* substance. Another explanation could be that because rain has no price, some people might interpret this as: *rain has no value*.

Source
1. **origin**; the place where something begins ….

..4. **beginning of a river** (geography); the spring or fountain from which a river or stream first issues from the ground
(From: Encarta Dictionary)

Etymology:
Source 1346, from O.Fr. sourse "a rising, beginning, fountainhead of a river or stream," fem. noun taken from pp. of **sourdre** "to rise, spring up," from L. surgere "to rise".

Sourdre: Sortir de terre (en parlant de l'eau)
(From: Dictionnaire du français primordial, Micro Robert 1980)

If one calculates the annual supply in a river basin as the sum of the volumes issuing from springs and the annual use as the total of withdrawals from rivers, streams and water bodies (lakes, reservoirs, ground water), then irrigation is the world's largest water user: 70 – 80% of global withdrawals are for irrigated agriculture. From the same perspective, it follows that countries that are confronted with water scarcity will single out the dominant use of water by irrigation as the major cause of their water scarcity problem. The solution, then, is likely to be primarily sought in limiting water allocations to the irrigation sector and improving productivity of irrigation water use. The latter part can also be stated in terms of reducing wasteful use of irrigation water, improving irrigation efficiency, considering water as economic good or using water according to its real value.

In the economic literature, the low price that farmers pay – if they pay at all – is stated as the main reason for wasteful use of irrigation water. The logical solution, then, is to charge farmers for irrigation water on the basis of its economic value. Numerous methods have been developed to determine this value, again from the perspective of water resources being limited to the water in rivers and reservoirs (including ground water).

Our perspective may change considerably by shifting the starting point of the analysis from the place where the water issues from the ground to the place where the rainfall reaches the ground. What happens to a falling raindrop depends on where it falls: soil, vegetation or sealed surface. Land use has a major influence on the way the rainfall is partitioned into infiltration and runoff. It is also the major factor determining how much of the infiltrated water evaporates and how much percolates to the groundwater. Again largely depending on land use, besides physical factors such as rainfall intensity, soil characteristics and topography, the rainfall (P, of Precipitation) is converted into a vapour outflow (E, of Evapotranspiration, also called *green water*) and a liquid inflow (P-E, also called *blue water*) into rivers and reservoirs. Figure 1 below shows the relative magnitude of these various components for the annual global rainfall on the land.

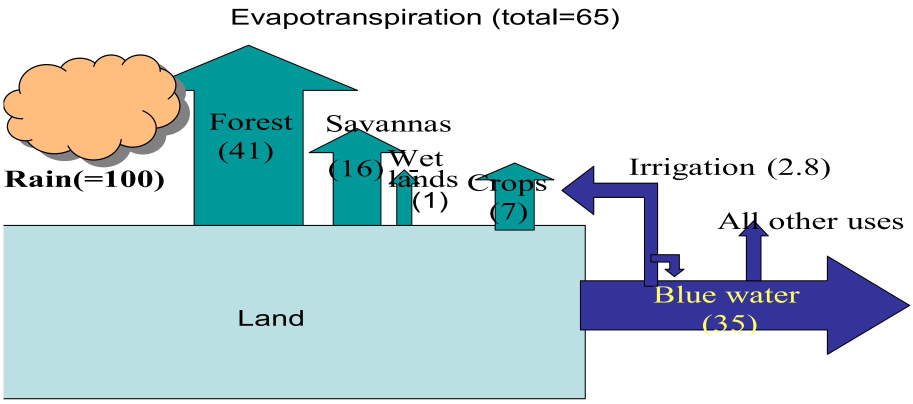

Figure 1. Partitioning of global rainfall. (After Rockstrom et al 1999)

While irrigation may be the world's largest user of water resources in the traditional sense, it only represents a minor percentage (2.8 % of global rainfall). It also shows that agricultural land (total of rainfed and irrigated agriculture) only uses 7% of the rain. The major users of rainfall, therefore, are the terrestrial ecosystems.

The ecosystems - and the agricultural land as well - may be considered as *processors of rainfall*, rather than as consumers. This is for three reasons; the first two are mainly technical:

- the land converts an input of rainfall into outputs of an invisible vapour flow and a tangible liquid flow into rivers, lakes and ground water;
- evapotranspiration from the land surface is an essential part of the hydrological cycle; large-scale reductions would have a major effect on rainfall.

The third reason is conceptual. Once we consider the land ecosystems as a processor of rainfall, with fresh water resources as one of its outputs, we are more ready to accept the view that ecosystems are *providers* of fresh water resources, rather than a new sector that is competing for water with the traditional water using sectors. This is especially relevant in the context of *water for food and ecosystems*, which, upon acceptance of the proposed view, would be more accurately described as: *ecosystems for food and water*.

2 Irrigation: Wasting the water

> Early in my experience of the project [a large engineering project in Nigeria at the end of the 1970's], I asked a young engineer what he thought of the idea of damming the river and intensifying agriculture through irrigation. His reply was simple, his conviction complete: 'It is the only way to stop the water running to waste.'
> …..I do not know where my engineer friend is today….But if he were here, I would ask him one question: *Who was wasting the rain*? Was it the farmers of the valley, or the multi-million pound irrigation scheme? With the benefits of hindsight, he would probably now agree that despite appearances, the farmer [growing crops using rainfall and river floods] was doing pretty well in difficult conditions. Despite its high-tech and grand plans, the irrigation scheme has turned out to be a terrible waste of money, human resources and…. water.
> From: W.M. Adams. 1992. *Wasting the rain: Rivers, people and planning in Africa.* Earthscan Publications Ltd., London.

In terms of global rainfall use, irrigation does not seem such a spectacular water user (Figure 1). For a particular river basin, however, the percentage of total rainfall withdrawn for irrigation can be much higher. In arid regions, irrigation often consumes the major portion of the water resources. This justifies an inquiry into the way the irrigation sector values and uses water.

For a farmer, irrigation is a way of dealing with the problem of unreliable or inadequate rainfall. A farmer is not likely to invest his resources in irrigation, until he has depleted the potential of other – less costly – alternatives for reducing his exposure to the risks resulting from inadequate rainfall. Even when he decides to go into irrigation, he will consider a range of irrigation options and evaluate each option on the basis of the degree of water security it offers in comparison to its cost. Most likely, the farmer will select a low cost irrigation option to begin with and gradually improve on it while gaining experience. When the resources needed for irrigation development exceed the means of the individual farmer, he may find other farmers willing to join forces. This will not fundamentally change the above course of action, even when farmers – individually or as a group- receive external support.

When the planning is done by a public or private organisation with an interest in developing an irrigation project, the process of planning and implementation is different. While low productivity due to inadequate rainfall is the stated reason for the project, the starting point in the design process is the infrastructure needed for conveying water from a source to farmers' fields. The financiers will require an economic analysis that shows an increase in the value of agricultural production enough to justify the investment and operational cost of the project. Agronomists will consult soil maps and climate data to assess the productive potential of the land under irrigated conditions. They also need an estimate for the production level for the *without project* situation. They will not spend a lot of time collecting these data: the lower the estimate, the higher the project benefits and the better the chance of obtaining funding.

As a result of this irrigation-infrastructure based development approach:

- Alternatives to irrigation are hardly considered.
- A standard solution is used for all farmers in the same irrigation project, irrespective of their individual need, ambition and competence levels in irrigated agriculture. [1]

Investment decisions are commonly based on the internal rate of return (IRR), which uses *physical*, *economic* and *design* data: soil, climate and crop data to calculate the increase in agricultural production, economic data to determine the increase in value, and engineering data for calculating the investment and operational cost. There are many ways for the planners to manipulate their data and arrive at an IRR that is high enough for obtaining financing:

- by underestimating value of production in the without project situation, e.g. by ignoring subsistence farming, products obtained from adjacent wetlands;
- by overestimating value of production due to irrigation, e.g. by assuming that all farmers will fully exploit the benefits of irrigation, all farmers will have full access to irrigation services and irrigation services will always be fully adequate for achieving potential production levels, all production will always be sold at the assumed market prices;
- by underestimating investment and operational cost, e.g. by letting a large group of farmers share a common outlet from the distribution system, on the assumption that farmers will organize themselves, leaving out other components that are essential for sustainable operation, such as flow control and measurement structures and drainage facilities.

The practices used in the economic analysis for investment studies for irrigation projects have estranged many of the actors in the irrigation sector from one another, as well as from the essentials of their professional task:

- Planners work with physical, economic and design data, rather than with farmers;
- Designers follow standard design procedures, rather than exploring options that correspond with needs of farmers, making use of the opportunities offered by the landscape and of local materials;
- Planners and designers not only avoid consulting with farmers but, also, with irrigation system managers: in the planning stage, this is because they can only expect to be told that the plans are unrealistic and that the design has many shortcomings; in the operational phase, it is because results indeed remain below expectations for the reasons just given;
- Unlike Newell in 1916 (see box), few irrigation managers today measure their success by the success of the farmers; only in exceptional cases there is a link between the income of the irrigation system manager and payments received for irrigation services;
- Irrigation engineers see their job as building, operating and maintaining an infrastructure for water distribution, instead of reducing farmers' exposure to the

[1] A participant from Laos in one of our irrigation courses summarized this practice as follows: *Instead of cutting the shoe to fit the foot, we are cutting the foot to fit the shoe!*

risk of inadequate rainfall. Due to lower remuneration, status and job satisfaction in system operation, they generally prefer construction to operation and maintenance.

> Newell: 'The management of an irrigation system has for its purpose the delivery of water to agricultural lands at such times and in such quantities as will enable the irrigator to produce the largest and best crops. The success of the manager is measured largely by the success of the farmer.'
> From: Newell, F.H. *Irrigation Management*. D. Appleton & Co. New York, 1916

Vicious cycles
Unsatisfactory performance of commercial enterprises is either fairly soon corrected or leads to bankruptcy, but government-run irrigation schemes tend to go from bad to worse. Over the last decade, agencies such as The World Bank have propagated irrigation management transfer (IMT)[2] as an escape from the vicious cycle of chronically shortage of funds for operation and maintenance (O&M) leading to lower farm income and lower capacity to pay for O&M, etc. These issues are discussed at length in the substantial literature on IMT. The discussion below will focus on two other vicious cycles in irrigation management, which both have to do with the failure to deal with the issue of uncertainty of irrigation services.

Uncertainty of irrigation services
The IMT literature mainly addresses the issue of uncertainty of irrigation services that result from inadequate financial and institutional arrangements for operation and maintenance of the irrigation *infrastructure*. However, many of the problems in irrigation management are caused by poor natural resource management, starting with the failure to recognize that irrigation is essentially a strategy for enabling farmers to cope with inadequate rainfall. While IMT seeks to transfer responsibility for the infrastructure, the implication of our argument is that in many cases the irrigation infrastructure will prove to be inappropriate, both from the perspective of the farmer and from the perspective of optimal use of water resources.

Planners who are hard pressed to meet the IRR investment criterion tend to make optimistic estimates about increased productivity due to the project. This optimism also extends to the assumptions made about water resources. In climates with high variability in rainfall, irrigation demand in an exceptionally dry year may exceed supply: the irrigation system that was assumed to provide farmers with full protection against inadequate rainfall cannot provide it anymore, due to … inadequate rainfall. When this situation has not been sufficiently anticipated in the planning stage, it depends on the inventiveness, motivation and cooperation of the various actors involved in the operation of the project, to preserve some degree of protection. The major challenge is to maintain a maximum level of *reliability* and *predictability* of irrigation services, in spite of the occasional water shortage. When these qualities are not preserved, irrigation deliveries tend to become unreliable even in years with

[2] It is ironic that international agencies have first "assisted" governments in developing irrigation projects without consulting farmers and later exert pressure on the same governments for transferring responsibility of these projects to farmers.

better rainfall, thereby developing into another vicious cycle. The vicious cycle caused by water shortage exacerbates the effects of the vicious cycle caused by shortage of funds for O&M and vice versa.
The water shortage induced cycle can even become more vicious due to two other factors that increase uncertainty:

- farmers who are confronted with insufficient or unreliable irrigation deliveries often respond by trying to obtain and store as much water as they can on their farm, thereby depriving other irrigators of their share and starting a vicious cycle of ever increasing uncertainty that may result in only a small part of the command area being cultivated while using the major part of the irrigation water;
- irrigation agencies that do not expect an adequate income from providing irrigation services to farmers will seek to maintain their power by building new projects or expanding the capacity of existing ones. This means that in stead of making every effort to reduce water uncertainty in the existing projects, irrigation agencies often increase the problem by their construction activities.

Irrigation agencies trying to survive by constructing new projects have every reason to downplay the issue of water uncertainty. They are greatly helped, in this respect, by international and bilateral funding agencies that still use the IRR as the main investment criterion. This is because the IRR only considers the return on capital, not on water! Most of the 280 or so million hectares that are currently irrigated worldwide are the result of a decision-making process about the allocation of capital! This means that the world allocates 70-80% of its total water use to a sector that – until perhaps very recently – had no particular interest in the productivity of that water, nor was it held accountable on that issue. Another implication is that in a particular river basin, the current allocation of water to agriculture is unlikely to represent the optimal allocation of water resources.

3 Saving the rain

…. I shall be telling this with a sigh,
Somewhere ages and ages hence:
Two roads diverged in a wood and I,
I took the one less travelled by,
And that has made all the difference.
Robert Frost (1874-1963),
cited in "*The Soft Path for Water*" (Wolff & Gleick 2002)

…. the diversion of almost 100% of the water from the Amu Dar'ya and Syr Dar'ya rivers in the former Soviet Union to grow cotton and other crops has led to the desiccation of the Aral Sea, the destruction of the fisheries there, local health problems, and the economic collapse of the region. Between 1926 and 1990, the surface area of the Aral Sea dropped 40% and the volume decreased 65%, and salinity has more than tripled. Reviving the Aral Sea may not be possible at all; it certainly cannot be done without a complete change in the style and form of water use in the region. Mukhammed Salikh, an Uzbek poet, said "You cannot fill the Aral with tears."
From: Gleick, P.H. 1993. *Water in Crisis: A Guide to the World's Fresh Water Resources.* Oxford University Press.

The Soft Path for Water

The picture on the front cover of Peter Gleick's publication *Water in Crisis* (1993) shows a fleet of fishing vessels on the bottom of the Aral Sea turned into a sand desert; all of the river water has been diverted for irrigation. The picture and the essays in the book convey the message that drastic changes are necessary in the way we manage and use our fresh water resources. For the 2002-2003 version of *The World's Water*, Gleick co-authored the introductory chapter: *The Soft Path for Water* (Wolff & Gleick 2002) Just like "demand management", the term "soft path" was first used in the energy sector, to indicate the changes needed for dealing with the oil crisis. The Rocky Mountain Institute later developed it into a strategy for the water sector. Wollf & Gleick define the soft path in terms of its differences from current practices – the hard path - in the water sector. The first characteristic is that 'The soft path redirects government agencies, private companies, and individuals to work meet the water-related needs of people and businesses, rather than merely to supply water.' As shown in the previous chapter, the vicious cycles that trouble the irrigation sector are primarily the result of irrigation agencies seeing their job as building and operating and maintaining an infrastructure for water distribution, instead of meeting the water related needs of farmers.

A Soft Path for Water

The Rocky Mountain Institute refers to the emerging paradigm of a "*soft path*" for water management. The terminology borrows from the energy soft path foreseen by RMI co-founder Amory Lovins in 1977. The energy soft path is characterized by highly efficient end-use technologies and widespread use of small-scale renewable energy resources—photovoltaics, wind power, biogas, hydrogen fuel cells, etc.—in contrast to continued proliferation of large, centralized fossil-fuel and nuclear power plants and continued reliance on fossil fuels for motive power. The water soft path is similarly characterized by wide use of diverse, often decentralized systems. Water supply, treatment, sanitation, and runoff management systems would be situation-dependent, but in general would be highly integrated physically and institutionally. They would take much greater advantage of local hydrologic resources (e.g., urban rainwater/stormwater harvesting and aquifer storage recovery systems versus distant surface supply and storage facilities); use the treatment capacities of urban watershed soils and vegetation to much greater stormwater management effect ("green infrastructure"); utilize all manner of wastewater treatment and reclamation systems and incorporate a high degree of reuse. The water soft path, like the energy soft path, places a strong emphasis on greatly increased efficiency in end use, precise management systems to avoid system losses, and matching of system components to the exact quantities and qualities required for appropriate classes and locations of end use. For example, supply and treatment systems would not be sized to provide drinking-quality water for landscape irrigation, nor for toilet flushing and other less quality-intensive uses. It is also possible to imagine how diverse methods and scales of supply and treatment could provide water of varying character—amount, chemical and biological quality, reliability of supply, and perhaps even temperature and other qualities—more cost-effectively than current systems. On the downstream side, a variety of wastewater treatment systems and scales could efficiently match the characteristics of the water to be treated and make it available for nearby or regional reuse.

Based on text from website of the Rocky Mountain Institute
(http://www.rmi.org/sitepages/pid278.php)

Table 1 summarizes six contrasts between the hard and the soft path for water. All of them seem highly relevant in the context of water for food and ecosystems. A promising concept is that of "*natural* (or *green*) *infrastructure*" (Table 1, under #5):

> 'Water is part of a natural infrastructure that stores and uses water in productive ways. The hard path, by ignoring this natural infrastructure, often reduces the amount and quantity of water available for use. The hard path defines infrastructure as built structures, rather than separating it into built (gray) and natural (green) components.' (Wolff & Gleick 2002)

In the context of *Water for Food and Ecosystems*, the 'natural infrastructure' deserves a prominent place:

- the 'natural infrastructure that stores and produces water in productive ways' are essentially the (terrestrial) ecosystems;
- when applying the fist characteristic of the soft path for water to the problem of farmers who are confronted with inadequate rainfall, the first thing to consider is how the natural infrastructure can be used for mitigating the adverse impacts; it is only after the potential of these "natural solutions" has been fully exploited, that one should turn to the "hard path" solutions involving built structures in concrete and steel.

Table 1: Six differences between the 'hard' and the 'soft' path for water
Based on: Wolff & Gleick (2002).

#	***Hard path*** **for water**	***Soft path*** **for water**
1	Expand capacity as demand increases.	Manage demand. Explore alternative options in meeting customers' water-related needs before increasing capacity.
2	Demand is in terms of quantity	Supply water of various qualities, reuse
3	Large, centralized, agency operated facilities	Includes option of decentralized investments
4	Agency meeting generic needs	Agency interacts with users to decide level of service
5	Ignores natural (green) infrastructure	Recognizes natural (green) infrastructure and the value of its services to users
6	Economies of scale	Economies of scope*

*) An economy of scope exists when a combined decision-making process would allow specific services to be delivered at lower cost than would result from separate decision-making processes. For example, water suppliers, flood control districts, and land-use authorities (e.g. local government) can often reduce the total cost of services to their customers by accounting for the interactions that none of the authorities can account for alone. This requires thinking about land-use patterns, flood control, and water demands in an integrated, not isolated way.

Somewhat surprisingly, both the Rocky Mountain Institute (see Box: *A soft path for water*) and Wolff & Gleick (2002) maintain the traditional perspective of the water sector: the water rising from the ground. Since they make the point about the water interacting with the natural infrastructure, one would expect them to recognize rainfall as the prime resource of freshwater. By starting with the rainfall, the entire area of the river basin *upstream* of the locations where the water emerges from the ground would then be added to the field of interest of the water managers. It would also substantially increase the volume of water that water managers can deal with: instead of optimizing the beneficial use of the runoff only, they would seek to increase the beneficial use of the total volume of rainfall. In other respects, however, the 'soft path' offers a way forward. We could perhaps rename this strategy: *A soft* *path for rain*. Given the vested interests of the traditional *hard path* players in the water sector, the soft path is likely to be quite tough. The recognition of the rainfall processing functions of the terrestrial ecosystems would therefore be more appropriately reflected by calling this new approach: *Land, Water and Ecosystems Management* (LWEM).

4 Land, Water and Ecosystems Management

The terrestrial ecosystems, or natural (green) infrastructure, besides 'storing and producing water in productive ways' (c.f. Wolff & Gleick 2002), are also the largest *consumers* of water through evapotranspiration. The first logical step in LWEM, therefore, is to identify and quantify the large water consumers in a particular river basin.

Data on land use, evapotranspiration and biomass production can be obtained by processing satellite images. Figure 2 presents land and rainfall use in India and Kenya.

It shows that India withdraws the equivalent of 16% of its annual rainfall for irrigation, which is substantially more than the 9% of rainfall consumed – through evapotranspiration - by agricultural crops. In Kenya, irrigation withdrawals amount to 0.3% of the rainfall, which is only a fraction of crop evapotranspiration (6% of rainfall). These percentages demonstrate the relevance of expanding the horizon of Land, Water and Ecosystem managers beyond that of the traditional irrigation or agricultural water manager.

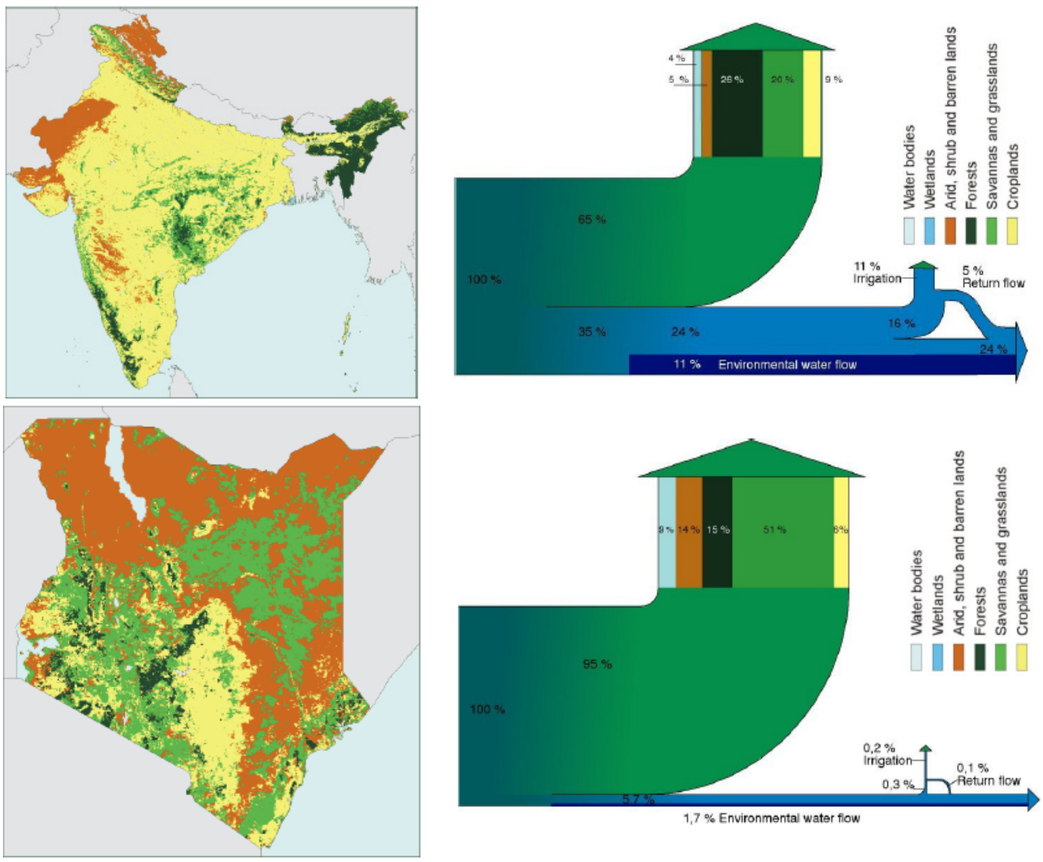

Figure 2. Land cover maps and rainfall partitioning for India and Kenya
Source: Rockstrom *et al* 2005

For a particular river basin, the data obtained by remote sensing need to be cross-checked with ground data, including rainfall, river flow and major withdrawals from ground and surface water. Even with fairly rough data, maps can be produced that by showing the current partitioning and use of rainfall, suggest options for resolving water scarcity problems through adaptation in current land use and water allocations.

Working out these options requires more detailed information than can be obtained with remote sensing. This is especially true for assessing the value of the benefits produced by each type of water use. In water scarce river basins, a change in land use or water allocation that will increase the benefits in one location is likely to reduce benefits elsewhere. Balancing the positive and negative results can only be done by the affected stakeholders in the river basin.

In addition to identifying options for dealing with water shortage on an annual basis, the LWEM approach also seeks to reduce undesirable effects of rainfall variability, by making use or improving the *natural infrastructure*. Variability of flow in rivers and streams is less than rainfall variability, due to the buffering effect of the soil. Water resources engineers construct dams and reservoirs to reduce this variability even further, in order to be able to meet the demand for water. With LWEM, there will be greater emphasis on seeking opportunities for increasing the buffering capacity of the soil, by increasing infiltration and retention of rainfall. These measures that are aimed at creating or augmenting natural water reserves in the landscape may be conceived of as *virtuous dams*.

A virtuous dam can be simply a cover crop that intercepts the direct impact of the rain on the soil, which would otherwise lead to reduced permeability of the topsoil, reduced infiltration and increased runoff. In addition to increasing infiltration and soil water storage, the cover crop also stimulates biological activity in the soil, which leads to better soil structure and internal drainage. Dr Robert Brinkman – a former chief of the FAO Land and Water Division – gave an example of an Italian vineyard owner, who solved both the problems of water shortage and water excess by sowing a cover crop, thereby avoiding the cost of installing an irrigation and drainage system (ILRI 1999).

Another example of a virtuous dam is the bunded rice field that is traditionally used for rainfed rice cultivation in the humid tropics. It creates a reservoir for keeping rainfall on the field, thereby enabling the farmer to overcome periods without rainfall.

5 LWEM and Irrigation

At some stage, the possibilities of dealing with inadequate rainfall by means of adaptations in the green infrastructure or virtuous dams may be exhausted or become incompatible with the level of technology used by the farmer. When this stage is reached, the farmer will be ready to resort to irrigation. World wide experience has shown that the smaller the group of farmers who share an irrigation facility, the better the chance of sustainable irrigation development. The implication is that governments should refrain from developing public irrigation systems until the limits of what farmers themselves can achieve have been reached. If public irrigation systems cannot be avoided, the way to avoid the vicious circles described earlier is the *soft path*. (Refer to Table 1)

1. **Meet water-related needs**: Irrigation is meant to reduce farmers' dependence on inadequate rainfall. Irrigation systems, however, also depend on rainfall. This means that irrigation can only provide a degree of security. The degree of security provided by the irrigation system must be compatible with the security-need of the farmer, which varies with type and input-level of the cropping pattern and, increasingly, with marketing arrangements.

2. **Supply water of various qualities**: In water-scarce river basins, the water drained from one irrigation project will affect the quality of the water for another project. Irrigation with treated urban waste water is also increasing. Water quality must be compatible with farmer's needs, which also depend on crops, irrigation technology, other production inputs and marketing.

3. **Decentralized investments**: Differentiation in water security and water quality leads to differentiation in types of irrigated agriculture, ranging from industry-like intensive horticulture to production of food grains near subsistence level. The horticultural industry should be able to arrange the major part of the investment themselves, while subsistence farmers are likely to remain dependent on public funds.

4. **Agency interacts with users to decide level of service**: An important element of LWEM will be a negotiated contract between farmers and the irrigation water supplying agency, which – like in an insurance policy – specifies the extent of security offered. For a farmer, this contract provides a level of security against erratic rainfall that could also be derived from a storage reservoir on his land; the contract, therefore, may be conceived of as a *virtual reservoir*. The box below describes the key elements of the service contract.

5. **Recognizes natural infrastructure**: Besides the level of service, the service-agreement will also specify the financial obligations taken on by the farmers. This arrangement will prevent farmers from entering into irrigation before they have exhausted the potential of the natural infrastructure.

6. **Economies of scope**: Irrigation, drainage and flood control agencies, domestic water suppliers and land-use authorities can often reduce the total cost of services by developing integrated plans.

Box: Key elements of the service-oriented approach for the restructuring of irrigation organizations

1. An irrigation organization is **service-oriented** when it (1) makes every effort to provide services that are well adapted to farmers' needs, (2) aims to provide these services at the lowest possible cost to its users, and (3) is accountable to farmers on the above issues 1 and 2.
2. A **Service-Agreement** between a service-oriented irrigation organization and its users specifies (1) The irrigation services that will be provided and the method used for checking that services are delivered as agreed upon, (2) The procedure for calculating the cost of these services to the users and the procedure for checking that services are delivered at the lowest possible cost to the users, (3) The consequences for each party of not fulfilling (parts of) the Service-Agreement, (4) The authority that will be addressed in case of conflicts, (5) The procedure for renewal, updating and improvement of the Service-Agreement.
3. For **large-scale systems**, irrigation and/or drainage water within the system is sometimes handled by several organizations. Such systems require a Service-Agreement for each level in the system where water is transferred from one organisation to the next. The set of Service-Agreements regulates the transactions between the organizations that provide irrigation and drainage services.
4. Organizations need to be **authorized** to make a Service-Agreement. For public-funded organizations, the manager or representative of the organization needs authorization from the ministry or department. In this authorization, restrictions or conditions may be imposed to ensure consistency with higher-level policies and especially with overall river-basin management policies. For Farmer Organizations or Water Users' Associations, the procedures for preparing, negotiating and signing the Service-Agreement must be described in an Organizational Charter.
5. The **Organizational Charter** specifies rules for behaviour within an organization. In addition to specifying procedures related to the Service-Agreement, it describes the purpose of the organization, the organizational structure and the procedures for electing council members and appointing functionaries, and the rights and duties of council members, functionaries and regular members.
6. **Service-oriented restructuring of irrigation organizations** is a process of identifying, designing and implementing the technical and institutional modifications needed for sustained operation of the system on the basis of an appropriate set of Service-Agreements and Organizational Charters. From: Dolfing, B. and W.B. Snellen. 1999. *Sustainability of Dutch Water Boards: appropriate design characteristics for self-governing water management organizations*. ILRI, Wageningen.

6 Valuation of water: an LWEM perspective

> I was sitting on a train the other day in England and found myself in a compartment with three gentlemen who were having a heated debate. I couldn't help hearing what they were saying, and I gathered that one of them was a surgeon, one was an architect and the third was an economist. They were discussing whose was the oldest profession. After a totally inconclusive debate finally the surgeon said, "Look here, come off it! I mean, there's no doubt: if you know Genesis, the Lord took a rib out of Adam to make Eve, and that was a surgical operation." But, unabashed, the architect said, "Well, long before He did this He had created the whole universe out of chaos: that was an architectural job." And the economist said merely, "And who created chaos?"
> From: E.F. Schumacher. 1979. *Good Work*. Abacus, London.

In 1992, water was declared an economic good. Many economists seem to have interpreted this as an official recognition of the validity of their economic concepts for resolving the issue of water allocation in irrigated agriculture. An example is the marginal utility concept:
'*The idea of "water as an economic good" is simple. Like any other good, water has a value to users, who are willing to pay for it. Like any other good, consumers will use water so long as the benefits from use of an additional cubic meter exceed the costs so incurred.*' (quoted from: Briscoe 1996)

According to the marginal utility concept, water should be priced at its marginal cost value and used until the marginal cost is equal to the marginal benefit. Briscoe, in the same paper, admits that it is very difficult to estimate the value of water to a user and even states: '*Most certainly these "ballpark estimates" can never, and should never, be used to make technocratic decisions on allocations and prices (as has sometimes been proposed).*' The marginal utility concept has been widely used to explain why most farmers – when given the chance – apply far more irrigation water than is required by their crops: because the irrigation fees they pay are much lower than the marginal cost value. Once diagnosed in this way, the obvious measure against wastage of irrigation water by farmers is increasing the price of irrigation water. This has resulted in a huge literature on water valuation and pricing, water markets, etc. In practical terms, very little was accomplished, due to objections raised by several groups:

- The development community on the grounds that price increases would put the water out of reach of the poor;
- The irrigating farmers on the grounds that price increase would erode their income;
- Other economists because a. the excessive cost of the additional infra-structure that would be needed for water measurement at the farm level, and b. the price level that would be needed to induce farmers to apply less water would be unrealistically high (e.g. Bosworth *et al*, 2002)

All these studies assume that farmers use too much water because it is cheap. Another possibly more important reason that farmers apply too much water is the unreliability and uncertainty of irrigation services.

> Just like city people will start hoarding whatever commodity is rumoured to become in short supply, farmers will try to store as much water as possible when they are uncertain about the timing and the amount of the next irrigation delivery. Their store room is the soil. Like the cellar in which the city dwellers store their hoarded goods, there is a limit to the volume the soil will hold. The difference is that the cellar has a solid floor, whereas the soil is open at the bottom. Water applied in excess of the soil moisture holding capacity will percolate beyond the root zone of the crops and therefore be lost. Farmers don't know exactly how much water the soil will hold, nor do they know the exact rooting depth. Agronomists and soil scientist have the equipment for determining soil moisture holding capacity and they sometimes dig a hole and determine the rooting depth at that particular spot for that particular stage of the crop. With this information, they can estimate – with some accuracy – how much water can be stored in the root zone of a field. But agronomists and soil scientists do not usually measure irrigation water. So, even with a fairly accurate estimate of the soil moisture holding capacity, these scientists cannot tell the farmer when his store room is full and he might as well stop irrigating. For the average farmer, the capacity of his storeroom is – even literally – a black box. Because he also does not know the volume of irrigation water that he is applying, he will be inclined to continue applying irrigation water until he feels quite certain that no more water will go into storage.
> The last cubic metre of water, therefore, is not applied for the purpose of equalizing marginal cost and benefits, but for increasing the crop's chances of surviving a period with unreliable irrigation.

For a farmer, the value of a cubic metre of water at a particular moment may vary by a factor 1000 or more, depending on the expected reduction in crop yield as a result of not receiving the irrigation water and the farmer's estimate of the reliability of the irrigation services he or she will receive for the remainder of the cropping season. The price that a farmer is willing to pay for an irrigation delivery at a particular moment, therefore, may be very much higher (or lower) than with an irrigation fee that is fixed prior to the growing season. The fixed irrigation fee that a farmer is willing to pay depends mainly on his or her assessment of (1) the irrigation agency's ability to provide adequate water, (2) the higher income expected as a result of the irrigation services. A key issue in determining the value of the water, therefore, is the reliability of the irrigation services. Reliability of irrigation services depends on a mix of natural factors, man-made infrastructure and management capabilities: variability in rainfall, available storage, priority rules for reservoir management, quality of reservoir managers, quality of irrigation managers, quality and state of repair of irrigation system, individual farm outlet or shared with other farmers and degree of co-operation among farmers. The water valuation methods currently used do not consider these factors.

Malano & Hofwegen (1999) advocate, as a common response to many other challenges facing the irrigation sector, 'the provision of an agreed or declared level of service that must be achieved at an agreed level of cost with customers'. From the above, it may be concluded that the negotiation of a service agreement provides a mechanism for incorporating the issues of uncertainty in the value of water. A contract that is negotiated between the farmers and the irrigation service providers specifies the extent of security offered. This contract provides the farmer with a level of security against erratic rainfall that could also be derived from a storage reservoir on his land; hence we have dubbed it a *virtual reservoir*.

The irrigation service providers, in order to be able to make commitments on water deliveries to farmers, will need to make similar contracts with the river basin managers or reservoir operators. These contracts will specify allocation priorities under various conditions of water availability.

The river basin managers, in turn, need to be guided by policy on how they should divide scarce water between social, economical and environmental purposes. Due to current water-legislation adopted in South Africa, for example, their river basin managers know that they can only allocate water for productive purposes (industry, irrigation) after basic needs (domestic water supply and environmental flows) have been met. The socio-economic value of this water depends on the political decisions taken rather than the other way around!

In many countries, a large part of the population is involved in irrigated agriculture and yet merely manages to produce enough to feed themselves. Under conditions of increasing water scarcity, governments need to make a choice whether to continue to allocate water to this group of people on social grounds, or whether they should allocate it to more productive use. The latter course would be a way of increasing national income, thereby enabling the country to import the food that is needed to feed the poor. Such food imports would make available a quantity of water – dubbed *virtual water* - that otherwise would have been used for food production.

For countries like Egypt, where there is hardly any rainfall, it is easy to establish the economic value of this 'virtual water': it is simply the value generated in its most productive use. In countries with variable rainfall, however, the value will vary with the rainfall: in years with abundant rainfall the value obviously is very close to zero. But even in dry years, it may be difficult to find an industry that can put the water to a highly productive use. This is simply because most industries that use water in their production process require a constant supply. The 'industry' that has a long tradition in coping with large fluctuations in water supply, is ……. agriculture. If we are to make the best of the available water resources, we need to identify ways to cope with the uncertainty of rainfall even better. Developing the institutional framework for increasing the value that can be obtained from rainfall seems more important than refining methodologies for establishing the value of water.

7 Conclusions

1. While the GWP definition of Integrated Water Resources Management (IWRM) refers to 'co-ordinated development and management of *water, land and related resources*', it still reflects the traditional focus of the water resources sector on the liquid water part (surface and groundwater) of the hydrological cycle. Especially in the context of water for food and ecosystems, much is gained by considering *rainfall* as the prime water resource. This shift in focus highlights the interactions between the land and the rainfall: it is the land that first separates the rainfall into runoff and infiltration and later into a vapour outflow (evapotranspiration) and a liquid inflow that recharges the (traditional) surface and groundwater resources.

2. Once we consider the land as a processor of rainfall, with fresh water resources as one of its outputs, we are more ready to accept the view that ecosystems are *providers* of fresh water resources, rather than a new sector that is competing for water with the traditional water using sectors. This is especially relevant in the context of *water for food and ecosystems*, which, upon acceptance of the proposed view, would be more accurately described as: *ecosystems for food and water*.

3. Recognition of the rainfall-processing functions of the terrestrial ecosystems would be appropriately reflected by calling this new approach: *Land, Water and Ecosystems Management* (LWEM). It could be considered as a component of IWRM for dealing with land, water and ecosystem interactions, rather than with the allocation of the (traditional) surface and groundwater resources among various uses.

4. Today's *land use* is the result of past decisions, made by many individual landowners who mainly considered the productivity of the *land*, *not water*. While they sometimes may also have considered productivity of the water resources, they will only have looked into the implications for their own property, not for the whole catchment. Even the investment decisions for public irrigation systems were largely based on the *return on capital*, not on the return on the water resources. It seems justified, therefore, to expect that in almost all catchments the value that is generated from the rain can be increased substantially, by adapting current land use and agricultural water allocations.

5. A first task in LWEM is to prepare maps of current land use in a rainfall catchment, the water consumption (evapotranspiration and major withdrawals) associated with the land use, and an estimate of the benefits from the water consumption. Benefits include ecological biomass production as plants and trees in forests, grassland and savannas, habitats for wildlife and biodiversity. A major function of these maps is to provide stakeholders in the catchment with an overview how the rainfall is used (or abused) under current conditions. Another function is to identify current and potential problem areas and the scope for improvement by changes in current land and water use. If such scope appears to exist, the next step is

to explore various alternatives, indicating the potential gains and the implications for stakeholders.

6. Because the majority of the existing irrigation projects were planned at a time when water scarcity was not considered a major issue, the investment decisions were based on the economic return on capital, not on water productivity. As a result, large volumes of water are currently allocated to irrigation projects with low water productivity. Due to inadequate financial and water resource management, many of the irrigation projects are in a poor condition and would require rehabilitation. From the LWEM perspective, irrigation is basically a strategy for coping with inadequate rainfall. Investments in public irrigation systems, therefore, should only be considered after farmers have exhausted the potential of reducing the risk of rainfall uncertainty by other means. The LWEM approach can assist farmers in identifying and using the potential of the 'natural infrastructure' for reducing the adverse impacts of inadequate rainfall, for example by seeking opportunities for increasing the buffering capacity of the terrestrial ecosystems, by increasing infiltration and retention of rainfall in the soil. These natural moisture reserves in the landscape may be conceived of as *virtuous dams*.

7. In LWEM, irrigation is considered as an insurance against uncertainty of rainfall, for which farmers must expect to pay an insurance premium. Since the irrigation water supplying agency also depends on rainfall, in regions with erratic rainfall it will not always be possible to supply farmers' irrigation demand. An important element of LWEM will be a negotiated contract between farmers and the irrigation water supplying agency, which – like in an insurance policy – specifies the extent of security offered. For a farmer, this contract provides a level of security against erratic rainfall that could also be derived from a storage reservoir on his land; the contract, therefore, may be conceived of as a *virtual reservoir*. Rather than putting a monetary value on the irrigation water, the service contract provides a structured and transparent mechanism that helps the farmer to express the value that the irrigation service represents.

8. In providing water services to their direct customers, irrigation system managers must take into account the interests of other stakeholders as well. These include downstream water users who are concerned about the effects of the irrigation system on water availability and quality. Society-as-a-whole, also, has an interest in water being allocated to uses that together generate a balanced mix of socio-economical and ecological values.
The LWEM approach aims at linking these various interests through a set of service-contracts; one for each level where the responsibility for water management is transferred from one party to another: farmer – water users' association (WUA) – water board (federation of WUA's) – irrigation system managers – river basin managers. Concerns raised at the higher level can be reflected in the conditions for allocation and use of irrigation water at a lower level. River basin managers, in turn, need to be instructed by policy-makers about society's choices, such as a preference for self-sufficiency in food or a reliance on imports of *virtual water*. A research challenge for LWEM is to provide the information that enables decision-makers at each level to make rational choices.

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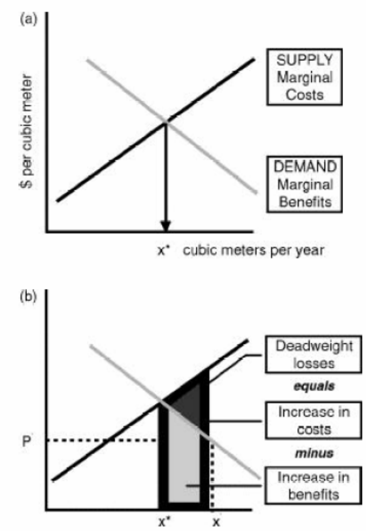
Annex: Economists ' misunderstandings about water management

A1. Briscoe's "simple idea"
John Briscoe - at that time Chief of the World Bank's Water and Sanitation Division - presented a paper *Water as an economic good: The idea and what it means in practice* at the 16th Congress of the International Commission on Irrigation and Drainage (ICID).[3]
According to Briscoe, '*The idea of "water as an economic good" is simple. Like any other good, water has a value to users, who are willing to pay for it. Like any other good, consumers will use water so long as the benefits from use of an additional cubic meter exceed the costs so incurred. This is illustrated in Figure 1 (a), which shows that the optimal consumption is X*. Figure 1 (b) shows that if a consumer is charged a price*
P^1, which is different from the marginal cost of supply, then the consumer will not consume X but X^1. The increase in costs (the area under the cost curve) exceeds the increase in benefits (the area under the benefit curve) and there is a corresponding loss of net benefits (called the "deadweight loss").*'



Briscoe's 'simple explanation' is based on supply and demand curves. These are theoretical constructs based on a number of assumptions, some of which definitely do not apply to water.

The ***demand curve*** *represents the relation between the quantity demanded and price* [of a commodity]*, other things being equal.*
The ***supply curve*** *represents the relationship between quantity supplied and price* [of a commodity]*, other things being equal.* (Lipsey *et al*, 1987)[4].

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[3] Briscoe, J. *Water as an economic good: The idea and what it means in practice.* Proceedings 16th Congress ICID, 1996. Special Session R.11, p. 178-201.
[4] Lipsey, R.G., P.O.Steiner and D.D.Purvis. 1987. *Economics.* 8th Edition. Harper & Row Publishers, New York.

Two examples of assumptions that do not seem to hold (water) are:

1. *There is always more than one commodity to satisfy a need.* While you can drink beer instead of water and flush your toilet with seawater, you cannot irrigate your crops with anything but (fresh) water! As the irrigation sector represents the largest demand for water, it does not seem correct to ignore the fact that the above condition is not fulfilled.
2. *There are many producers in a competitive market.* This condition is not fulfilled, as domestic water or irrigation water, in most cases can only be obtained from one provider.

Many more reasons why economic principles do not readily apply to water are given in the literature. (e.g. Perry *et al* 1997[5], Savenije 2001[6]). The two above, however, are sufficient to reject Briscoe's interpretation of '*water as an economic good*'.
Perhaps even more fundamental than the two assumptions discussed above is the fact that water – unlike most economic goods – is not made by a producer who supplies quantities of water in accordance with anticipated demand or price: to date, nobody is capable of planning or controlling the amount of rainfall (or snow)! This means, simply, that the concept of a supply curve cannot be applied to water.

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[5] Perry, C.J., M.Rock and D.Seckler. 2001. *Water as an Economic Good: A Solution, or a Problem*? Research Report No 14. International Irrigation Management Institute, Colombo, Sri Lanka.

[6] Savenije, H.H.G. *Why water is not an ordinary economic good, or why the girl is special.* 2nd WARFSA/WaterNet Symposium: Integrated Water Resources Management: Theory, Practice, Cases; Cape Town, 30-31 October 2001.

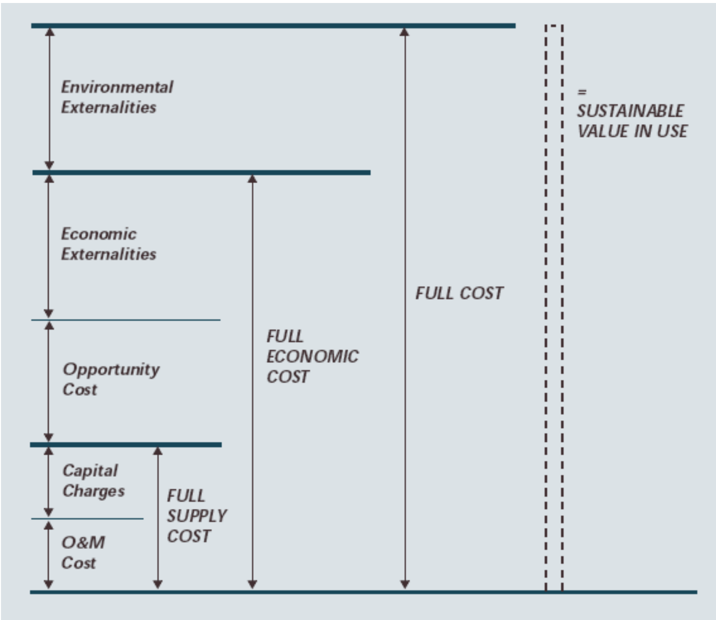
A2. Opportunity cost[7]

The Global Water Partnership produced a brochure to explain the practical implications of the principle that water should be recognized as an economic good. The figure below is reproduced from this document; as is the following statement:

> *'Regardless of the method of estimation, the ideal for sustainable use of water requires that the values and the costs should balance each other; full cost must equal the sustainable value in use.'*

This "ideal" is not explained in the GWP brochure. From another paper by the same principle author (Rogers, P. *Integrating Water Resources Management with Economic and Social Development* . UN CSD 1998 Background Paper):

> *'Water tariffs are typically based, at best, on average cost pricing (rather than marginal cost pricing or market clearing prices) and* ***typically ignore the opportunity cost of water*** *(i.e. benefits foregone in alternative uses). Similarly, the effects of damages caused by industries in polluting surface and groundwater are ignored in determination of water tariffs and typically there are no pollution taxes and/or effluent charges to be paid by industrial polluters in developing countries. As a result, excessive quantities of water are used, and excessive pollution is produced.'*



General principles for the cost of water (Rogers, Bhatia and Huber, 1998)[8]

Briscoe (1996)[9] discusses the costs of water service provision in urban water supply and irrigation. In urban water supply the *Full Supply Costs*[10] are high compared to the

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[7] **Opportunity cost**: 'The cost of using resources for a certain purpose, measured by the benefit given up by not using them in their best alternative use.' (Lipsey et al 1987, ibid)

[8] Rogers, P., R. Bhatia & A. Huber. *Water as a social and economic good: How to put the principle into practice.* TAC Background paper no.2, Global Water Partnership, Stockholm, 1998

[9] ibid

[10] *Full Supply Costs* are called *Use Costs* in Briscoe's paper

Opportunity Cost; in irrigation this is just the opposite. The author remarks that '*Ignoring opportunity costs is thus a matter of minor practical importance when it comes to the economic management of urban water supplies,* ***but a matter of huge practical significance when it comes to irrigation***.'

In his paper, Briscoe already qualifies his own statement by differentiating between four options for redistributing irrigation water:

A. Water can be used only by one individual farmer
B. Water can be sold to neighbouring farmers
C. Water can be sold within an Irrigation District
D. Water can be sold to any other type of user.

The importance of the Opportunity Cost increases from A to D. The possibility of redistributing water to another place depends largely on the type of infrastructure for water distribution and storage. In terms of physical infrastructure, conditions for redistribution are optimal if water is stored in a multi-purpose reservoir and distributed through a pipe system that extends all the way from the reservoir to the individual farm. In terms of alternative uses, conditions are better in the vicinity of -respectively- high value agriculture, urban and industrial centers. It is clear that the options for redistribution appear considerably greater in industrialized areas with modern irrigation infrastructure (pressure pipes) than in rural areas with large-scale gravity irrigation systems (open canals).

Briscoe must be credited for discussing the infrastructure-related effects on opportunity cost, which is often overlooked by others (including those agronomists who fail to see that a water saving practice is only relevant when the saved water can be directed to another place where it can be beneficially used). He makes no mention, however, of how opportunity costs are affected by uncertainty. This seems especially relevant in irrigation, where both the demand and the supply of irrigation water are hugely affected by rainfall.

After heavy rainfall, a farmer who receives a scheduled irrigation supply cannot use it on his own farm, nor is he likely to be able to sell it to any other farmer. Theoretically, there is the option of selling it to another user. This requires transportation of the water to that other user, which represents a cost. It is doubtful whether there are users willing to incur these costs when it only provides them with water only when farmers have no use for it. In practice, therefore, there is no alternative use and hence the opportunity cost is zero.

FAO Land and Water Bulletins No. 3[11] includes an overview of economic issues in water sector planning. A statement under the heading **Opportunity costs and pricing** (p.72) also uses *variability* as an argument for not incorporating opportunity cost in water pricing:

[11] Water sector policy review and strategy formulation - A general framework. *FAO Land and Water Bulletin* No. 3, 1995 (E)

'It is impractical to incorporate opportunity cost into a standard pricing formula because of the extreme spatial and temporal variability and the difficulty of dis-aggregating multiple alternative uses.'

A3. Ecological economics

'Ecological economics helps us make more sustainable water resources decisions in three important ways. First, it provides a needed *theoretical* revision to neo-classical economic analysis. Second, this theoretical perspective points us toward better *methodologies for measuring* the value of competing uses. Third, it helps us identify the program of *institutional reform* that has the best chance of delivering more sustainable water resources management.' (Lant, 2004) [12] [Italics as in original text].

Neo-classical economics considers only manufactured capital (i.e. infrastructure) as essential to economic production. From the ecological economics perspective:
Economic production in the medium-to-long term depends on natural, human, manufactured, intellectual and social capital. The ecological economics perspective, therefore, seems to offer a considerable improvement over traditional economic theory.

When it comes to putting a value on these other types of capital, however, even those economists who are critical of neo-classical economic theory seem to find it difficult to do without the traditional economist's toolbox:
'For environmental services their opportunity costs is the net benefit foregone because the resources providing the services can no longer be used in their next most beneficial use.' (Tietenberg 2003)[13]. Tietenberg apparently can only appreciate the value of a natural resource by calculating the value it would have generated when used for some productive purpose.

Costanza *et al* (1997)[14] calculate the value of ecological services as the sum of producer's surplus plus consumers' surplus. These surpluses are derived from what seem to be based on "regular" marginal supply and demand curves that are adapted for the purpose of valuating ecosystem services.

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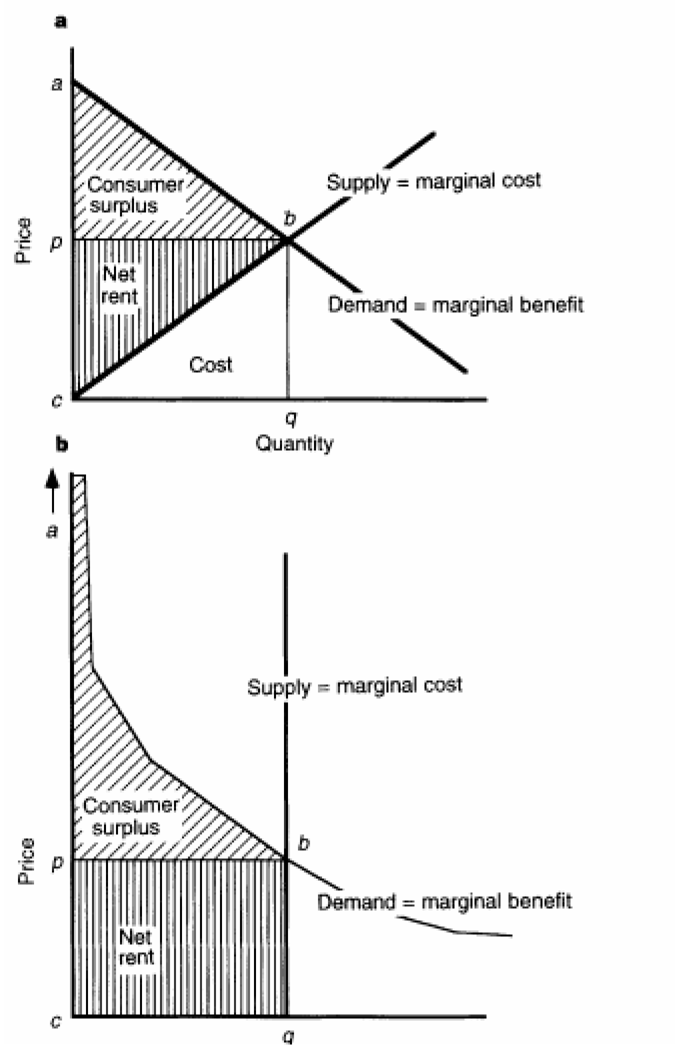
[12] Lant, Ch. Water Resources Sustainability: An ecological economics perspective. *Water Resources Update* 127, pp 20-30, February 2004.
[13] Tietenberg, T. 2003, Environmental and Natural Resource Economics, 6th Ed. Boston
[14] Costanza et al. The value of the world's ecosystem services and natural capital. *Nature* **387**\15 May 1997 p.253-260



***a** and **b**. Supply and demand curves, showing the definition of cost, net rent and consumer surplus for normal goods (**a**) and some essential ecosystems services (**b**). Source: Costanza et al 1997.*

Figure (a) presents the supply and demand curves for human-made substitutable goods; Figure (b) gives the adapted curves for ecosystem services. As explained by Costanza *et al*, the demand for ecosystem services approaches infinity as the quantity available approaches zero. The implication is that consumer surplus (and therefore economic value) approaches infinity as well. It is not difficult to imagine that someone who is dying of thirst is willing to pay any price for a glass of water by. This hardly seems a valid approach, however, to establish the value of that water. The supply curves for ecosystem services is vertical, because – according to Costanza *et al* - they “cannot be increased or decreased by actions of the economic system.” This raises the question what this supply curve (or vertical) is supposed to represent.

Another method used by the ecological economists for assessing the value of water is by establishing the price difference between houses overlooking water and similar houses without such a view. This is what in the valuation literature is called the

Hedonistic Pricing Approach (HPA). Hedonistic refers to Hedonism, which - according to Longman's dictionary of contemporary English – is "the practice of living one's life purely for pleasure". Another valuation method used by ecological economists is the Travel Cost Method, which determines the value of nature in a specific location by the amount of money people spend to travel to that location. In a review publication on "the value of nature valuation" for the Dutch Ministry of Agriculture, Nature and Food quality, these methods are presented as tools for what can be translated as a "Societal Cost Benefit Analysis[15]" or SCBA (Almasi *et al* 2004)[16]. The publication describes the SCBA as being based on welfare economics, in which individuals decide on the allocation of goods or services *that have alternative uses*. It seems somewhat out of place to apply valuation methods such as the Hedonistic Pricing Approach and the Travel Cost Method under conditions where choices have to be made about allocation of natural resources for societies that are in the process of exceeding the carrying capacity of their ecosystems. When natural resources such as water are becoming so scarce that a reduction in their allocation for ecological purposes threatens the very survival of these ecosystems, the criterion of *having alternative uses* for the resources no longer applies. This means we should not think in terms of welfare economics anymore! It is rather cynical that while one group of ecological economists is trying to convince the general public that they need to reduce the size of their ecological footprint – for example by reducing their air travel – another group is advocating techniques such as the Travel Cost Method, which values nature by the amount of money people spend on (air) travel.

A4. Hydro-economics

Peter Rogers, Harvard Professor in economics and author of the Global Water Partnership Technical Background Paper No. 2, *Water as a Social and Economic Good: How to Put the Principle into Practice*, advocates a new branch of economics:
"*To appreciate fully water policy options and how they are evaluated* ***it is necessary to understand how economics is used and misused in the water area****. This paper*[17] *motivates the* ***need for a more erudite and focused branch of economics dealing specifically with water****. This branch is called* ***hydroeconomics***."

Rogers presented a methodology for examining the impacts of water resource management decisions on the macroeconomy and vice-versa. The methodology uses Leontief's Input-Output Analysis for examining the value produced by water in various sectors of the national economy. For explaining the approach, Rogers presented the Water Sector Balance for Morocco (1995).

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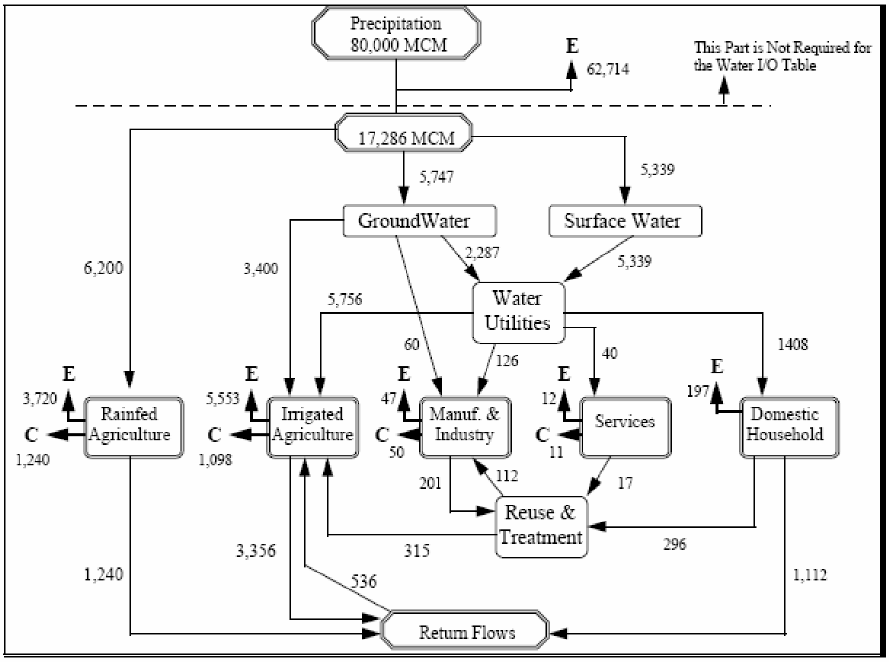
15 Translation from Dutch: "Maatschappelijke Kosten-Baten Analyse (MKBA)"

16 Almasi, A. *et al*, 2004. *De waardering van natuurwaardering. Een "state of the art" document* (in Dutch). Expertisecentrum LNV, nr. 276.

17 Rogers, P. *Preparing for the future. Hydroeconomics: Getting water into national economic planning.* P65-82 in: Stockholm International Water Institute. *Proceedings of Mar del Plata 20 years anniversary seminar*. Stockholm, 1997.

Figure 1: Water Sector Balance for Morocco - 1995



E = Evapotranspiration
C = Volume embedded in the economic product
C/E (Rainfed Agriculture) = 0.33
C/E (Irrigated Agriculture) = 0.20

Examination of this Water Balance raises a number of puzzling questions: Why is there a different C/E ratio for rainfed and irrigated agriculture? The plant retains a certain percentage of the water it takes up from the soil and incorporates it into its tissues, including the economic product. The plant, so to speak, couldn't care less whether the water it takes from the soil is irrigation water or rainwater. We would expect, therefore, that the C/E ratios are about the same.

A more puzzling question: how can this C/E ratio be so very large? A "normal" Y/E ratio between the yield (Y) of the harvested product (e.g. Y = 5 tons of wheat) from a field of 1 ha and the total evapotranspiration E from the same field during the growing season (e.g. E = 5000 tons of water) is 5/5000 or 0.001. A "normal" moisture content of the product at harvest is around 20% . In our example, this means the volume of water embedded in the economic product (C) would be 1 ton (or 1 m^3), giving a C/E ratio of 1/5000 (= 0.0002). The numbers given in Figure 1 would imply that 1000 tons of water is embedded in 5 tons of wheat!

Another puzzling question is why irrigated agriculture receives zero rainfall? This could be the case in Egypt, where there is no rainfall to speak of. In Morocco, however, rainfall varies between 100 and 700 mm per year and the irrigated agriculture is practiced in the same regions as rainfed agriculture. Hence, irrigated agriculture should receive a comparable share of the rainfall.

The most puzzling – and even alarming - question, however, is why the hydrologists in the audience have not observed these fairly obvious errors. Rogers delivered his presentation at the Stockholm International Water Institute, during the Mar del Plata 20 years Anniversary Seminar in 1997. A dissertation by Hynd Bouhia[18], a PhD student of Rogers, and published in 2001 contained the same figure as presented above, with exactly the same numbers. Here too, while the title of Bouhia's dissertation claims *integration of economics and engineering*, there were apparently no scientists in her examination committee who took the trouble of checking the hydrological part of the dissertation.

Apart from the errors in the hydrological part, it seems odd to use Leontief's Input-Output Analysis for evaluating the effects of various water policy measures on water productivity in the different sectors at macro-economic level. As pointed out by Leontief, this type of analysis is based on the assumption that intersectoral exchange of products and services is relatively *stable*. The whole point of an analytical model for evaluating the effects of various water policy measures is to see which policy is the most effective in bringing about desired *change*.

[18] Bouhia, H. *Water in the macro-economy: Integrating economics and engineering into an analytical model*. Ashgate Publishing Group, 2001.