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UFOPLAN Project

"Development of strategies and sustainability standards for the certification of biomass for international trade"

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Contents

List of figures

List of Tables

Abbreviations

BOD	Biochemical Oxygen Demand
CC	Cross Compliance
COD	Chemical Oxygen Demand
DFID	Department for International Development
DSS	Data Synthesis System
EEA	European Environment Agency
EPER	European Pollutant Emission Register
EROS	USGS Earth Resources Observation and Science Center
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GAEC	Good agricultural and environmental conditions
GAP	Good Agricultural Practice, community agricultural policiy in EU
GAP2 Modell	Model of the University of Kassel
GFP	Good Farming Practice
GlöZ	Guter landwirtschaftlicher und ökologischer Zustand
GTOPO30	Global Digital Elevation Model (DEM)
GTZ	Deutsche Gesellschaft für technische Zusammenarbeit GmbH
GWAVA	Global Water Availability Assesment
HRT	Hydraulic Retention Time
IHP	International Hydrological Program
IRENA	Indicator Reporting on the Integration of Environmental Concerns into Agricultural Policy (EU)
IUCN	International Union for the Conservation of Nature and Natural Resources
IWMI	International Water Management Institute (Sri Lanka)
POME	Palm Oil Mill Effluent
SADC	Southern African Development Community
SMR	Statutory Management Requirements
TDS	
TKN	Total Kjeldahl Nitrogen
TRIP	Total Runoff Integrating Pathways

TS	Total Solids
TSS	Total Suspended Solids
TVFA	Total Volatile Fatty Acid
UASFF	Up-flow Anaerobic Sludge Fixed Film
UBA	Umweltbundesamt (German Environmental Agency)
UNEP	United Nations Environment Programme
UNEP-RBIS	UNEP Global River Basin Information System
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNH	University of New Hampshire
WBSCD	World Business Council for Sustainable Development
WHO	World Health Organization
WMO	Word Metrological Organization
WRI	World Resources Institute (University of New Hampshire)
WSAG	Water Systems Analysis Group
WSM DSS	WSM Prototype Decision Support System
WSM	The WaterStrategyMan Project
WTO	World Trade Organisation
WWAP	World Assessment Program
WWDR	World Water Development Report

Selection of some important definitions

(also refer to Chapter 3)

Water availability – available water resources:
The amount of freshwater available per capita per year (acc. to UNESCO).
Available amounts include total water quantities from renewable groundwater and surface water.

Water scarcity:

Various attempts have been made at defining this term by referring to

a.) the situation when available water supplies are no longer adequate to satisfy all human or ecosystem requirements, resulting in increased competition between water users and demands (UNEP 2002)

b.) water scarcity as the situation when *water supplies* drop below 1,000 m³ per person per year

c.) *physical water scarcity* as characterized by a high relation of water quantities withdrawn with respect to the available water supplies (e.g. > 0.75)

d.) *economic water scarcity* as the situation where the population cannot financially afford access to the resources, although physically water resources are sufficient

Water stress:

Again, various attempts have been made defining

a.) water stress as a situation that precedes *water scarcity*: *water supplies* dropping below 1,700 m³ per person per year (Falkenmark, Widstrand 2002)

b.) water stress as characterized by a certain relation of water quantities withdrawn with respect to the available water supplies
(e.g.: >0.4: severe stress; 0.2-0.4 mid stress; 0-0.2: low stress, refer to EEA 2005a)

1 Introduction

1.1 Purpose and tasks of this report

One of the key issues of global expansion of biomass production is the question of how far the quantitative availability and the qualitative status of water as a resource or subject of protection would be affected.

The cultivation of crops necessarily requires adequate water supply. The water demand depends not only on specific cultural factors (e.g. specific demand of crop planted, size of cultivation area) but also on locational factors (mainly quantity and distribution of precipitation, groundwater regimes, water resources available for irrigation).

If the water resources available have already been strained by the existing cultivation systems and/or other consumers, one has to expect that additional cultivation or an intensification of farming will increase pressure on the water resources. The term availability of water resources has a key function. Its measurement is influenced by:

- the natural availability of groundwater and surface water (landscape hydrology)
- climatic impacts (especially the seasonal distribution of availability)
- the economic availability (distribution problems, competition of use).

The potential withdrawal of local or regional water resources, or water as a subject of protection, by additional or intensified biomass cultivation will result in the following problem areas:

- Increase or induction of water competition and the potential conflicts resulting from such competition
    a) between water users of the various segments (agriculture, industry, private households)
    b) between riparians or various groups of the population
    c) with respect to environmental and nature conservation objectives (water protection, ecosystem protection, biodiversity)
- Pollutant emissions to waterbodies
- Negative ecological consequences of (inappropriate) irrigation

In view of the chain of production of bioenergy carriers, it must also be noted that water is not only needed for cultivation, but occasionally also when processing biomass in conversion plants.

The core task of this study focus as part of the “BioGlobal” research project is to work out practical criteria and indicators for the assessment of the problem areas outlined above in the context of sustainable production and use of biomass and bioenergy.

The legal requirements are primarily based on the EU *Renewable Energy Directive* (2009/28/EC), and especially Articles 17 and 18 of the Directive containing the requirements on the "**Water**" issue, which should be satisfied in the light of sustainability. Member States are called upon to require market operators to provide information on the **measures taken**

- for soil, **water** and air **protection**
- **to avoid excessive water consumption in areas where water is scarce**

and to document these measures (Article 18, No. 3, Para. 2)[1].

In accordance with Article 17 No. 6 of Directive 2009/28/EC, the **protection of groundwater and surface water quality** primarily depends on compliance with the EU legislation on agriculture (cross-compliance), although this legislation is limited to the Member States. The "spirit" of these provisions concerning a "good agricultural and environmental condition" should also be applied beyond the scope of EU standards. This primarily refers to an appropriate limitation of the quantity of fertilizers used.

The present report

- analyzes the relationship between biomass cultivation and water
- interprets the terms availability of water and scarcity of water
- analyzes the background of competing use with a view to potential origination or aggravation of water scarcity,
- discusses the need for as well as the requirements and limits of sustainability indicators in connection with "water" within a certification system
- analyzes the indicators or indicator models available, and
- proposes suitable applicable indicators or indicator models with special emphasis on the need
    - to make reference to the requirements of the Renewable Energy Directive and evidence of compliance in practice
    - to clarify whether reference is exclusively made to regions with water scarcity
    - to select a suitable "scarcity definition" (physical, natural, economic)
    - to find a suitable approach for defining excessive consumption (only irrigated farming? to which extent? including rain-fed farming?)

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[1] For detailed information concerning the requirements laid down in Directive 2009/28/EC with respect to water, refer to Annex **Error! Reference source not found.**.

  - to determine the effective depth with respect to local / regional conditions (climate / structure of water use as a whole and by sectors / effective consequences on the water balance) and an appropriate spatial resolution
  - to verify the availability of data for the application of the indicators
- is designed to present the proposed indicators as an approach for assessing locations under the aspect of availability of water and waterbody protection (including pollutant emissions from agriculture and industrial use).

1.2 Water – a scarce commodity?

As a raw material, water cannot be increased in quantity, nor can it be "destroyed" as an element. However, there are considerable global differences as regards the distribution or the availability distribution of water. Whether or not a commodity is scarce depends on the relation between the demand for it and its local availability.[2] Other differences refer to the seasonal availability in many regions. Therefore, the term "scarcity" is complex in nature and characterized by different definitions, depending on the circumstances. The definitions of water scarcity, water stress etc. will be dealt with in detail in Chapter 3.

For the population affected, sufficient availability or the lack of water are among the most fundamental means of livelihood. Since the last decade, UNEP (1999) has determined water scarcity in many regions of the world, especially in the semi-arid regions of Africa and India. The same applies to various regions both in Europe and in North and Central America. In potential biomass production countries with high population growth, water competition may become more fierce as a result of an increasing demand for drinking water if it is already scarce today and biomass cultivation is economically viable only if additional water is used for irrigation. The effects of world climate change on the water situation are still totally incalculable (refer to Chapter 0).

The highly diverse manifestations of "scarcity" in different parts of the world are demonstrated by the strongly deviating patterns of use – both in relative and in absolute terms. In countries with a generally low use (and rather low availability) agriculture has a fairly high relative share in water use already today. For example, in Mozambique, Zambia and Zimbabwe, between 76 % and 87 % (FAO Aquastat 2005) of the total water quantity utilized are used in agriculture for irrigation. Water use of sometimes more than 90 % for irrigation is assumed by WBCSD (2005). In a country such as Mozambique, the total water use per person is much lower than the proportionate use by

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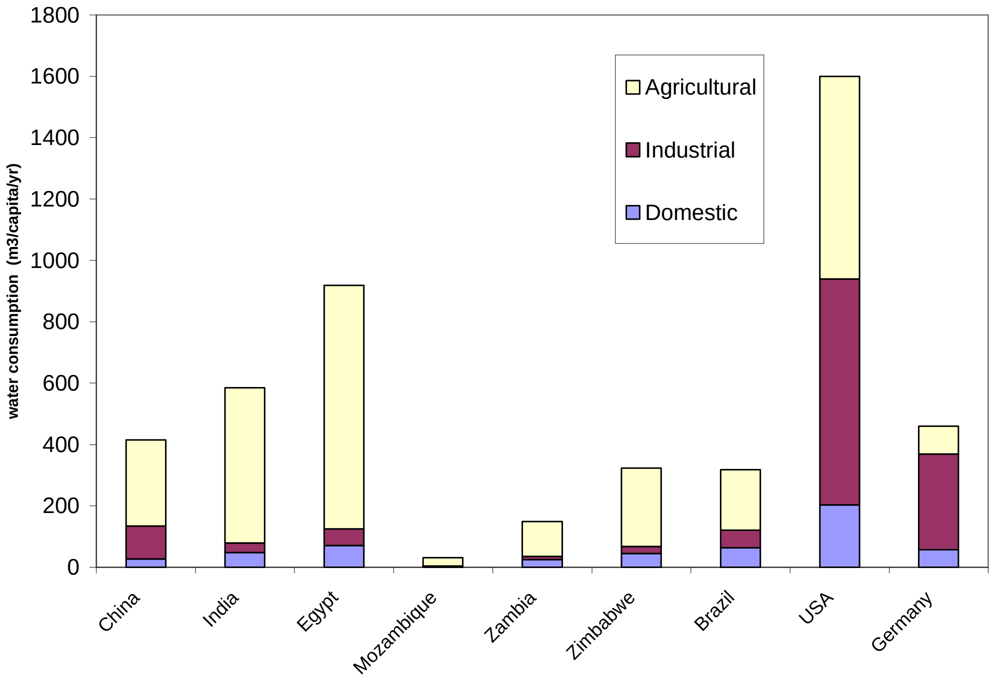
[2] Although one also has to ask about the spatial dimension in which local availability is to be seen, because water can be transported over certain distances.

agriculture in Germany (refer to Figure *1*). The figure shows the great differences in total water use and the use of the individual sectors between the countries depicted.

Figure 1 *Annual water use per person in selected countries*



Source: Data from "The World's Water 2008-2009 Data, Update 2006"; *www.worldwater.org*

As a result, special challenges are experienced by countries or regions

- which already show signs of water scarcity
- where a significant/major proportion of water use is attributable to agriculture
- where water demand is increasing in other sectors (drinking water supply, industry)
- that are characterized by strong population growth
- which experience problems with water management and drinking water supply

The problems are not restricted to those countries/regions where all aspects apply, as demonstrated by incidents of crisis caused by a lack of water in Australia and the U.S. Lack of water is the most frequent cause of crop failure. The local/national population is not necessarily the one that suffers most. Crop failure results in a price increase of the agricultural produce concerned, so that the effects on staple foods eventually affect poor countries that depend on staple food imports.

The cause-effect relationship of sufficient vs. insufficient availability of water is a highly complex and extremely sensitive one.

2 Problem area “Water competition through additional biomass cultivation”

The present section will deal with the possible relationship between additional or intensified biomass cultivation and potential consequences on the availability of water resources. The public is aware of the possible emergence of conflicts between intensified biomass cultivation and water supply which is the subject of frequent discussions. Landmark analyses of the interrelationships were first prepared by Berndes (2002). A very recent discussion of the issue is found in Hoogeween et al. (2009).

As already shown in the previous section, specific water use is very high in countries where cultivated land is historically irrigated (refer to Figure *1*) and agriculture is the biggest water consumer. When moving close to the limit of exhausting the water resources available in these regions, one has to expect that additional, yield-oriented cultivation will almost inevitably result in situations of water stress or scarcity. This will be even more the case since in the countries concerned, an increasing need for water has often emerged in other sectors as well (domestic consumption, industry).

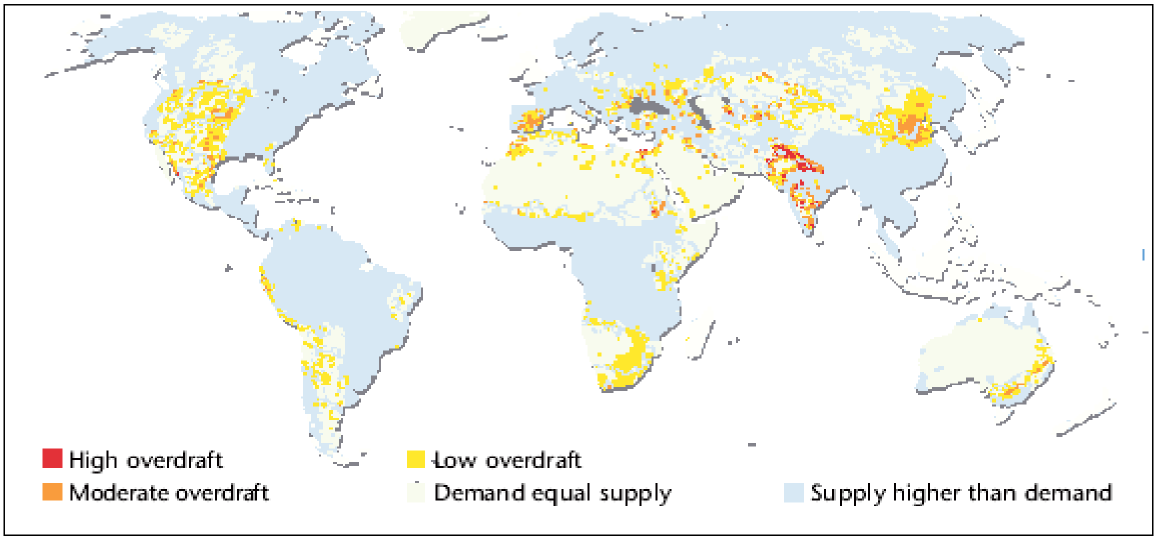
In addition, it must be noted that the choice of types of bioenergy crops will also determine the demands on water supply (refer to Chapter 4) since not only the traditional regional crops cultivated for food production may be used as energy plants, but also other crops (such as fast-growing grass species or eucalyptus in short rotation).

2.1 Irrigation and its consequences

Irrigation is an absolute must in many regions if agriculture is to ensure sufficient food production. Approx. one third of field crops are produced on one sixth of the cultivated land under irrigation worldwide. The yield of field crops on land under irrigation is practically twice as high as in rain-fed farming (Stockle 2001), and this factor even increases with the aridity of the climate (FAO 1992). Due to this high productivity, which is often achieved by several crops per year, irrigation is an important element for satisfying the growing need for food.

Regardless of whether irrigation is used in agriculture in order to produce food or biomass, it can have various negative environmental and/or socio-economic impacts, especially if water withdrawal is high. Figure 3 shows an analysis prepared by Millennium Ecosystem Assessment (2005) indicating that even today, massive overdraft of water resources and a “non-sustainable” withdrawal of water are taking place in various regions of the world, especially on the Indian subcontinent. The definition of the quantities, or their limits, referred to in the legend for Figure 3 is not indicated in the source quoted.

Figure 2 “Non-sustainable” water withdrawal for irrigation



Source: Millenium Ecosystem Assessment (2005)

The move towards or the intensification of irrigation farming is often associated with radical change in land use.[3] Figure 3 shows a diagrammatic depiction of the potential direct and indirect consequences of irrigation on environmental media and the socio-economic area. It is mainly based on the effect analyses developed by Stockle (2001).

Especially noteworthy is the fact that total water use is subject to additional local or regional change as a result of intensified irrigation and the accompanying change in social structures (emergence of settlements, infrastructures). Possible direct negative consequences on the water balance (groundwater and surface water), soils and eco-systems may mutually influence, or even reinforce each other through a combination of many different factors.

Another problem results from the fact that the irrigation technique is frequently not very effective in many countries, causing not only excessive water consumption, but also an increase in negative side effects. For this reason, water scarcity in many countries is not necessarily related to availability, but also associated with the lack of technology or insufficient financial power (Schopp et al., n.d.).

Below, you will find examples of a number of particularly relevant cause-effect relationships in connection with consequences of irrigation:

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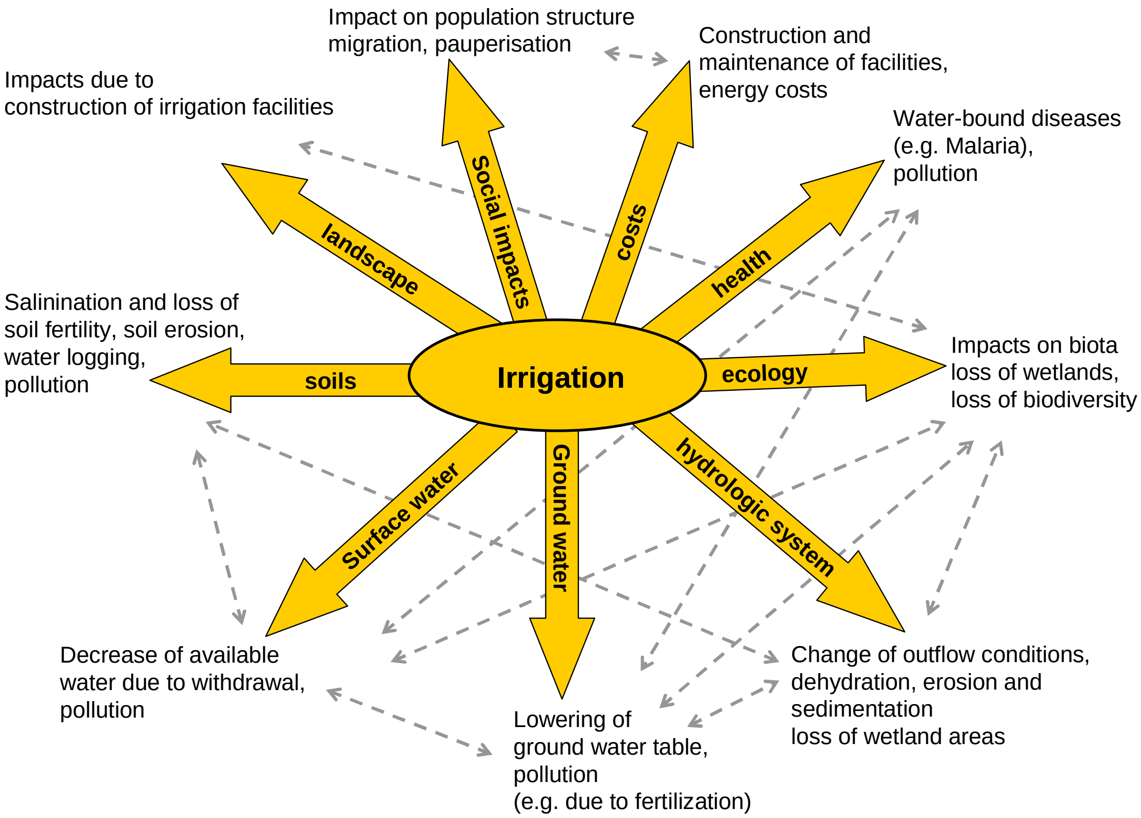
[3] A specific problem exists if cultivation of irrigated land is changed from the previous food crops to energy crops. This change qualifies as an indirect change in land use. There is no local increase in water use, however, it can be assumed that the displaced food crops will be produced elsewhere, if necessary, using irrigation again.

Dramatic **hydrological changes** may occur as a result of water withdrawal for irrigation, which may lead to partially dry rivers (e.g. Save) or those which can no longer reach their original estuaries and the sea, as demonstrated by the Colorado River (U.S.A.) and the Yellow River (China) (Stockle 2001). In return, this will negatively impact the ecosystem. Negative effects, like the Save River (Zimbabwe/Mozambique), can be traced back to inappropriate or inexistent water management resulting from very intense irrigation in agriculture. The same effect has also been observed for inland lakes. The best-known example is the sedimentation and salinization of the Aral Sea. The water supply to the Aral Sea was dramatically reduced by water withdrawal and diverting rivers to canal systems.[4]

Figure 3: Possible negative impacts of irrigation on environmental media and the socio-economic area (solid arrows) and examples of indirect cause-effect relationships between these media and areas (dashed arrows)



Source: own chart according to FAO (1995), IWMI (2007a), Stockle (2001)

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[4] http://www.aralsee.org/

More hydrologic impacts on the groundwater / the groundwater balance are possible. For example, withdrawals from groundwater may

- result in a drawdown of the groundwater table
- or in higher groundwater salinity.

Heavy water withdrawal (from surface water and groundwater sources) may result in a **drawdown of the groundwater table**. Consequences often include severe impacts on the environment or the sustainability of agricultural use. For example, heavy water withdrawals in Texas for irrigation purposes since 1980 are blamed for the approx. 14 % loss in cultivable land suffered since that time, because the dramatic change in the hydrology balance has increasingly reduced the amount of water available for cultivation. In other regions where irrigation is frequent, such as Punjab (India), a drawdown of water tables by 1 m or more per year has been observed (Stockle, 2001).

Soil salinity is a big problem on a worldwide scale. It could result in declining crops on more than 25 - 30 % of cultivated land under irrigation in the U.S. Estimates for Mexico assume a 1 million ton decline in cereal yield per year as a result of soil salinity. This amount of cereal would be sufficient for feeding almost 1 million people.[5]

Wastewater is an important source for irrigation in regions in which water supply is already low. Wastewater is sometimes treated and degermed before being used, and sometimes it is not. Irrigation using wastewater is quite common in Kumasi (Ghana), Dakar (Senegal), Nairobi (Kenya), India, China, but also in the U.S., for example. This popular irrigation method, which is used for 10 % of global crops in accordance with the first global survey of wastewater irrigation according to Scott, Director of IWMI Asia, has a number of most diverse consequences. Pollutants are emitted to the soil, but on the other hand, the inputs of, e.g., K, N, P serve as fertilizers and increase yield. In addition, high-quality water resources can be protected by using wastewater for irrigation. On the other hand, the health risks resulting from toxic substance accumulation in the human food chain should not be underestimated (IWMI Asia 2004).

Soil erosion as a result of runoff from cultivated land may become a considerable problem in case of excessive irrigation and modified soil properties, depending on the type of irrigation practiced (Stockle, 2001). Depending on the location, slope of cultivated land, type and scope of plant coverage, pollutant input in waterbodies may occur in addition to soil erosion. Runoff is higher on land with low plant coverage. The loss of the humous topsoil aggravates the problem, because the topsoil has a higher water retention capacity than the soil substrate. Soil erosion also reduces the fertility of the soil, as shown by numerous studies (IWMI 2007a), (McCartney et al. 2007).

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[5] State of Washington Water Research Center: http://www.swwrc.wsu.edu/newsletter/fall2001/irrimpact2.pdf

The **social consequences** of irrigation are extremely diversified and cannot be studied in the scope of the present working paper. It should only be pointed out that in addition to possible negative consequences (drinking water shortage, consequences of interventions in the social structure of rural areas), irrigation is associated with quite a number of positive effects that justify irrigation in many cases. Thus, higher yields naturally result in greater wealth and are a means of combating poverty, as evidenced by Rijsberman (2004) by examples from India, the Philippines, Thailand and Viet Nam. Accordingly, in tropical regions with rain-fed farming at least part of the population suffers greater poverty than in regions practicing irrigation.

2.2 Are problems to be expected from rain-fed farming as well?

Rain-fed farming is practiced on approx. 80 % of cultivated lands worldwide (IWMI 2007). One condition for rain-fed farming is a sufficient water supply of cultivated land from rainfall, and that the crops grow well with the water that is naturally available.

As a result, the problem of water competition does not arise in this context because no water sources are utilized to satisfy the needs of other sectors. However, it should be discussed at this point whether or not this “acquittal” of rain-fed farming from causing any type of water competition can be generalized.

Two basic problems arise in this connection:

- First, the interaction between the cultivation method and the associated vegetation structure (above and below ground) on the one hand and the water regime on the other can be very complex and not always directly predictable.
- Second, a distinction between irrigated and rain-fed farming is becoming increasingly difficult to make because most diverse intermediate forms have emerged.

One **intermediate form** that is interesting in terms of development technology is proposed by IWMI (2007), recommending rain-fed farming supplemented by water storage to bridge phases of water scarcity, or an optimized version of rain-fed farming. In this case, it will be the question of effective water quantities that will decide whether such practice may also result in significant changes of hydrological systems.

With respect to the different forms of **“classic” rain-fed farming**, the influence on the hydrological balance is expected to be rather insignificant. Existing water scarcity will eventually be reflected by low growth or low yield. However, it must be noted in connection with changing crop rotation (and on the background of climate change) that individual rain-fed cultivation areas may become irrigated farmland if their use is changed and energy plants are cultivated – provided that the economic boundary conditions are satisfied in the individual case. For example, a trend towards “rain-fed irrigation” or “micro-irrigation” has recently emerged in various regions of Africa. These terms refer to rain water collection and storage during the rainy season, which is then used to extend the cultivation period and protect the harvest (Rockström et al. 2004). The projects themselves have to verify on the basis of the actual situation that these concepts do not interfere with the water balance resulting in scarcity. It is expected that negative effects will be rather insignificant, whereas benefits identified include a significant protection of yields, mainly in regions where the rural population is extremely poor, or which are particularly affected by climate change and the resulting uncertainty of crops (Rijsberman 2004) (refer to Chapter 2.1).

The relevant questions to be asked are, how the cultivation system is laid out, and which crops are selected. Again, highly complex dependencies are present in such cases. For example, direct interaction between crops cultivated and the groundwater regime can only be assumed if bigger woody plants are involved.

This would refer to, e.g., agro-forestry systems as well as short-rotation plantations. It must be noted, however, that tree-grown systems normally resemble the natural, undisturbed vegetation. Negative consequences on the hydrological system (drawdown of the groundwater table) should not be expected. Agro-forestry systems may even have positive effects compared to pure crop farming, because the rows of trees, if properly aligned, shadow the farmland and/or protect it against wind, thus reducing evapotranspiration (van Noordwijk et al. 2006).

Possible negative effects would have to be expected from short-rotation plantations of tree types that withdraw high water quantities (willows, poplars, eucalyptus). If large plantations of these kinds of trees are built up in locations with low precipitation on soils with a low water storage capacity, high evaporation may result in groundwater depletion, or at least a reduced groundwater renewal rate (NABU 2008).

2.3 Problem: what is the adequate spatial resolution?

The question concerning the spatial reference unit is of key importance for the assessment of the hydrological effects of a biomass cultivation area (e.g. as part of a certification process). In contrast to biodiversity, where higher resolutions are generally assumed to be more appropriate, water is normally more adequately described in larger spatial contexts. An excessively fine resolution that would basically provide isolated results would not be commensurate with the character of widely spread relationships between hydrological units. Therefore, the dramatic influence on an individual, small creek may be more acceptable in an overall assessment than a slight reduction of the water regime in a wider region of which the dimensions are nevertheless more significant.

In this discussion, the availability of data is a particularly limiting factor. Data concerning the availability of water is often available at the national level, or at the level of river catchment areas with further subdivisions. A coarse resolution at the national level and at the level of the total catchment area of a river is not sufficient for the detection and assessment of the consequences of water withdrawal for irrigation purposes.

2.4 The problem of climate change

Despite all forecasts and models, the exact consequences and effects of the global climate change have remained entirely incalculable.

Various models developed under the umbrella of IPCC[6] concerning the effects of climate change on the water economy (water balance, changes in runoff and precipitation, groundwater components, vulnerability of freshwater resources, regions with water stress etc.) arrive at partly different results as regards changes of the relevant parameters. For countries in the semi-arid regions of Africa and India, forecasts mostly predict deterioration in the precipitation conditions (UNEP (1999), Mendoza, Villanueva, Adem (1997), Oki et al. (2003), as well as Oki and Kanae (2006)). Another study of Kim, Oki et al. (n.d.) has assumed that total precipitation will increase in Asia, Africa and North America on the basis of models.

For most regions in Africa, forecasts of the annual change in precipitation until 2080 indicate changes from 0 to -10%, and in some regions – mainly in West Africa – this value may drop to as much as -20%. According to calculations using the HadCM3 model[7], changes between 0 and +10% are to be expected in the equator region.

The Umweltbundesamt (German Environmental Agency) has also performed various research projects and activities to work out foundations and data on this complex issue, such as the preparatory and final documents for the Climate Change Symposium in February 2007[8], the report on “Impacts of climate change on water resources – adaption strategies for Europe” (Ecologic/PIK 2008)[9], papers for the “Konferenz im Rahmen der Entwicklung der Deutschen Anpassungsstrategie an den Klimawandel (DAS) (German Climate Change Adaptation Conference)“[10] and the Themenblätter zu Klimaschutz Landwirtschaft (Theses on Climate Protection – Agriculture).[11]

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[6] HadCM2, HadCM3, ECHAMA4, ECMA4, CGCM2 CSIRO MKI

[7] http://www.cambridgeconservationforum.org.uk/symposium_2006_presentations_PDF/Hole%20-%20Impacts_CC_African_IBAs.pdf
(only secondary source – Basis IPCC, reference will be provided later)

[8] http://www.climate-water-adaptation-berlin2007.org/

http://www.climate-water-adaptation-berlin2007.org/background.htm

[9] http://www.umweltdaten.de/publikationen/fpdf-l/3630.pdf

[10] http://www.wasklim.de/BMU-Konferenz.htm#Hintergrund

[11] http://www.umweltdaten.de/klimaschutz/landwirtschaft.pdf

3 Core aspect: Water availability vs. water scarcity

The terms water availability and water scarcity are of key importance in the present paper. The aim is to derive key indicators on the topic from these terms. It must be noted that some indicators have already been applied to global assessments (refer to the maps in *Figure 4* to Figure 6), which are also applicable to local, individual cases. While the former approach may be suitable for a top-down assessment and coarse zoning of "regions with water scarcity", the actual consequences of a project will have to be subjected to local assessment ("excessive water consumption").

The definitions of the terms water availability, water scarcity and water stress given in literature will be summarized below.

3.1 Water availability

The attempts at defining *water availability* found in literature are not very precise, and are normally used in a direct context of (partly synonymous with) the term *water resources*.

The **FAO** (2003) does not provide its own definition of *water availability*. It defines *water resources* under two different aspects:

- *renewable water resources:* total resources that are offered by the average annual natural inflow and runoff that feed each hydrosystem (in km³ per year)
- *exploitable water resources:* the water resources considered to be **available** for development under specific economic and environmental conditions (e.g. dependency on flow, extractable groundwater, and minimum flow) (in km³ per year).

The FAO report discusses lack of clear definitions of the terms *"water availability"* and *"water resources".* For the sake of clarity, it recommends using "water availability" in the sense of *exploitable water resources* in order to avoid confusion with water offer.

In its report on "Water Scarcity and Droughts", the **EU** (DG Environment 2007) defines the term *"renewable water resources"* analogous to the concept presented by the FAO:

> The total *renewable freshwater resource* of a country is the total volume of river run-off and groundwater recharge generated annually by precipitation within the country, plus the total volume of actual flow of rivers coming from neighboring countries.

This resource is supplemented by water stored in lakes, reservoirs, icecaps and fossil groundwater.

Webb and Iskandarani (1998) back up the concept that *water availability* must account for ecological factors for better assessment of the amount of renewable water resources available for human use.

While the FAO approach expresses the resource, and thus the availability, as km³ per year, the German Environmental Agency[12] defines the quantity as the annual renewal amount of water (groundwater and surface water) per person. This creates a link to the criteria for water scarcity and water stress (refer to next Section).

3.2 Water scarcity and water stress

Different definitions have been provided in literature for water stress and water scarcity, although these concepts are closely related. Falkenmark, Widstrand (2002) and other authors interpret "stress" as a predecessor of "scarcity".

Two approaches of a quantitative definition of these terms have been made:

a) by a certain amount of water (in per cent) withdrawn from the total water resources available

b) by the availability of water (renewable water resources) per person per year

Alcamo et al. (2003) have always defined water stress in connection with water use (or approach a) and water scarcity according to approach b.

The first approach in itself offers different methods:

First, in order to quantify water stress, water withdrawal (in %) with respect to (total) water availability, as shown in *Figure 4* and Figure 6, above, may be considered.

Another method applied under this approach distinguishes between physical, approaching physical and economic scarcity, as shown in Figure 5. According to IWMI (2007), the classification is defined as follows:

- Little or no water scarcity: abundant water resources are available relative to use, with less than 25% of water from rivers withdrawn for human purposes.
- Physical water scarcity: More than 75% of river flows are withdrawn for agriculture, industry, and domestic purposes. This definition - relating water availability to water demand - implies that dry areas are not necessarily water scarce.
- Approaching or expected physical water scarcity: More than 60% of river flows are withdrawn. These basins will experience physical water scarcity in the near future.
- Economic water scarcity: Water resources are abundant relative to water use (less than 25% of water available is used), but malnutrition exists.

A comparison between the two figures (*Figure 4* and Figure 5) shows that there are clear differences between regions with water stress and water scarcity, depending on the different approaches, and that – depending on the approach – regions may be affected by water scarcity in one figure, while they are not on the other map.

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[12] http://doku.uba.de/cgi-bin/aDISCGI/aDISWebUBA/lib/adis.htm?ADISDB=TH&ADISOI=00608935

The second, most frequently used approach developed by Falkenmark (1989) originally expressed water stress subject to the population to be supported per *flow unit* (1 million m³ of water per year). The purpose of this definition was to emphasize that the number of persons per *flow unit* was the most important factor (Ashton, 2002).

This index leads to the following:

Excellent conditions (abundance)	<100	people / flow unit
Central European conditions	100 – 600	people / flow unit
Water stress	600 – 1000	people / flow unit
Chronic scarcity	1.000 – 2.000	people / flow unit
Absolute water scarcity	>2.000	people / flow unit

Source: Ashton (2002); 1 Flow unit = 1 million m^3 of water

Falkenmark and Widstrand (2002) modified the original quantification approach made in 1989, now relating the definitions of water stress and water scarcity to the “availability” per capita per year. This approach is referred to by the model definitions developed by other authors that have been summarized in Table 1. This leads to a simplification, however, the aspect of the population to be supported is no longer present (Ashton 2002).

Figure 6 (top) shows the global representation of water availability for the year 2000 on the basis of this approach.

A study performed by EAWAG (Zehnder, 2003) approximately supports the limits specified for water scarcity and arrives at the conclusion that a country can no longer adequately feed its population if the water available per capita per year is less than 1500 m³.

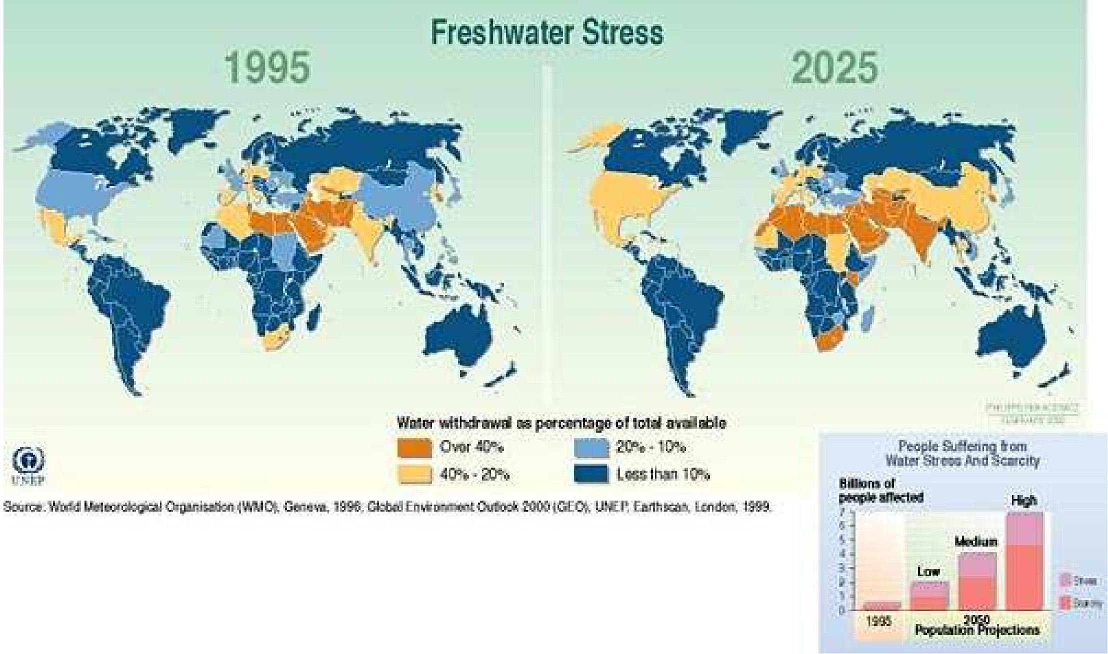
Table 1 Different definition limits of water stress and water scarcity

	Falkenmark und Widstrand (2002)	Liebscher (n.d.)	UNEP (2000)	Webb and Iskandarani (1998); Asheesh (n.d.)	
Reference m^3/ (person x year)	water availability	water availability	available renewable freshwater resources	internal renewable freshwater availability	
≤500	absolute water scarcity	acute water scarcity	extreme water scarcity		🟥
<1000	chronic water scarcity		water scarcity	water scarcity	🟨
<1.667				water stress	🟨

<1.700	water stress		water stress		🟨
<1.750		periodic water scarcity			
<4.000	no stress	occasional water stress	no stress	no stress	🟦
<10.000		sufficient water supply			
>10.000		abundance of water			🟦

Source: own compilation

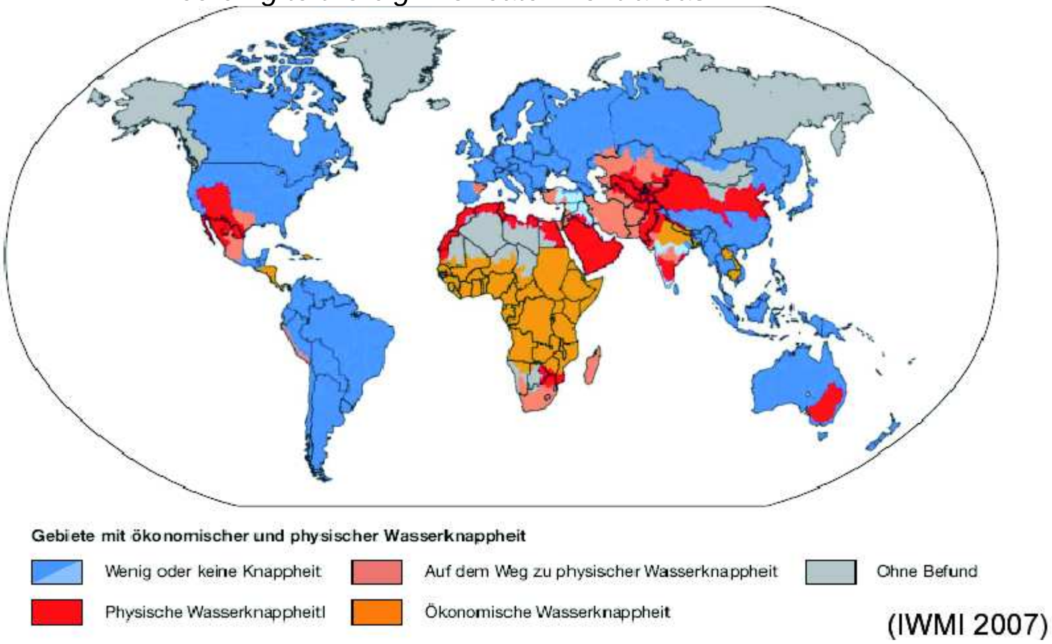
Figure 4: Water stress under the aspect of water withdrawal as a function of water availability (total) – resolution at country level



Source: World Meteorological Organisation (WMO), Geneva, 1996; Global Environment Outlook 2000 (GEO), UNEP, Earthscan, London, 1999.

Source: http://www.unep.org/dewa/assessments/ecosystems/water/vitalwater/21.htm

Figure 5: Regions with physical and economic water scarcity – resolution according to the big river catchment areas



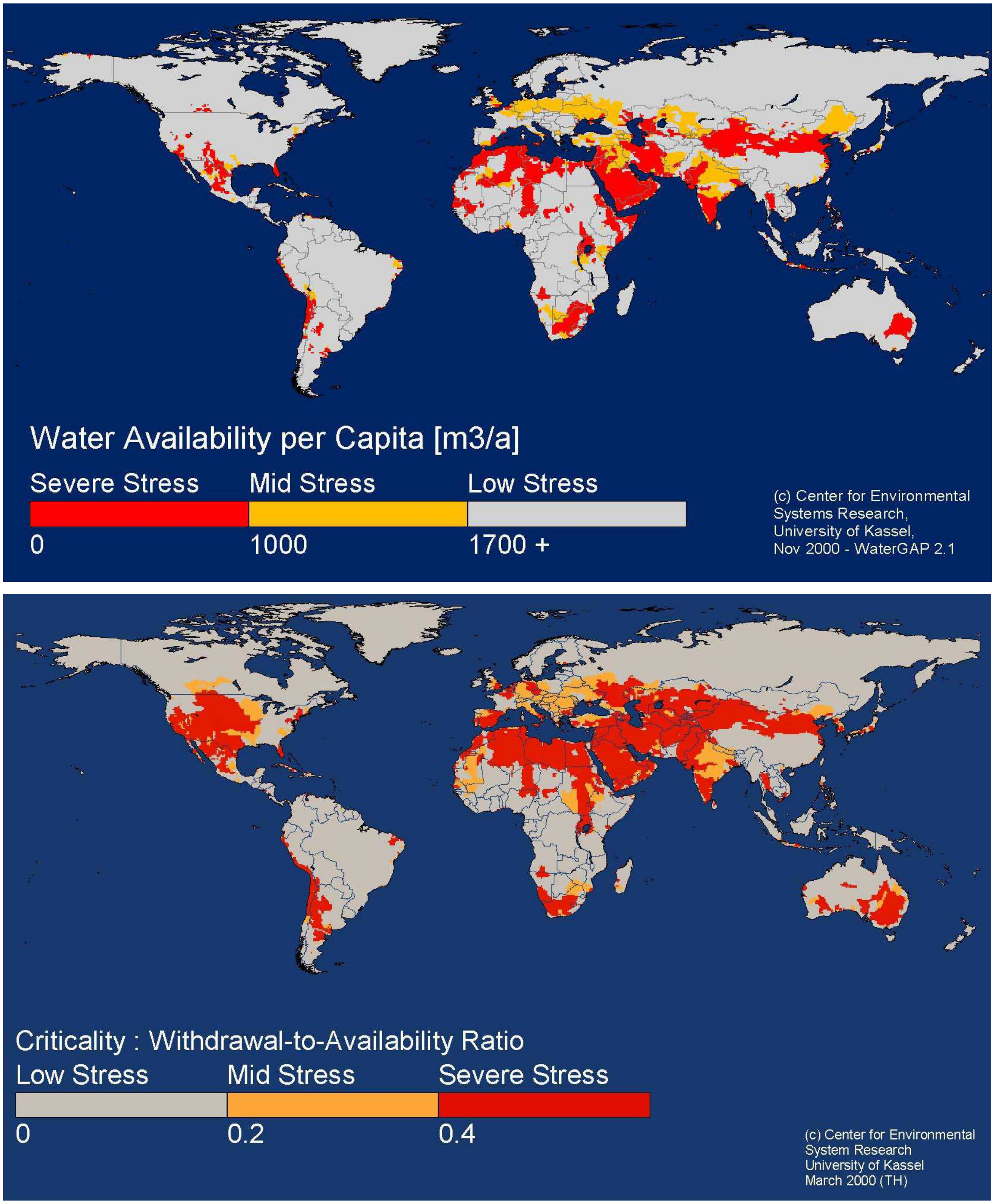
Source: http://earthtrends.wri.org/updates/node/264

The approach made by the University of Kassel (Alcamo et al. 2003), which is to be seen in the context of the so-called “water stress index” (refer to Chapter 3.2, Table 3) is based on the relation between annual withdrawal and annual availability. Figure 6 shows a comparison of global analyses of availability (in m³/(capita x year)) and water stress (use/availability ratio), whereby the resulting ratios were assessed as follows:

0 to 0.2	- low stress
0.2 to 0.4	- mid stress
above 0.4	- severe stress

These categories were also used by EEA (2005a) for including “water stress” in its system of indicators for assessing the situation of the environment in Europe.

Figure 6: *Top: Global distribution of the availability of renewable water resources in* m^3 *per capita per year in the year* 2000;
Bottom: Calculation of various levels of water stress expressed as the ratio between annual withdrawal and annual availability
fine resolution, calculated using WaterGAP 2.1 (source: University of Kassel)



4 Evaluation of existing approaches – possible methods of assessing water competition

The foundations for an assessment of water availability, scarcity and stress were outlined above, including some proposed and established models that are useful in this connection. These scientific approaches, data and models that were previously prepared to describe the water economy/balance globally or for individual regions and can be utilized for the assessment with respect to biomass cultivation, will be summarized in the following sections.

The present chapter has been subdivided as follows:

- a summary of the key data (databases) and influencing variables used for the indicators and indices
- the possible indicators and/or indices
- examples of applications and models

4.1 Influencing variables

4.1.1 Data acquisition of water resources available

According to the FAO (2003, 2005), the two most important components for taking stock of the existing amount of water include

- internal renewable water resources
- and external renewable water resources

This includes the following data: surface water and groundwater data, precipitation, surface runoff, river runoff, new groundwater formation, groundwater flows, surface water inflow from neighboring countries, water inflow to rivers and water inflow of the rivers to the aquifer.

The FAO Aquastat module provides a tool for the detailed collection and calculation of water availability data at the national level.

4.1.2 Acquisition of water use data

Water use data is subdivided into the industrial, household and agricultural sectors.

Water use varies regionally subject to the climate, cultural preferences and economic factors. In Germany, for example, the daily personal consumption amounts to 126 liters per person. According to Kürschner-Pelkmann (2003), the minimum water demand per person amounts to 25 liters (including drinking, cooking, hygiene).

According to Gleick (1993a), 100 liters per day and person should be available, the WHO assumes a minimum of 150 liters (Asheesh n.d.).

The crop-specific water demand in agriculture varies according to vegetation phases and country (Hoekstra 2002). The CropWat Support System Tool (Version 5.7) developed by the FAO (1992) may be used to determine this demand as well as the reference evapotranspiration, however, different methods are provided for calculating the crop coefficient with regard to different measured variables.[13]

The FAO publishes water use data of various groups of crop and types of crop in various growing stages[14] [15]. Other data on country level was provided by Hoekstra et al. (2002).

In order to draw up a balance sheet of water demand, “monthly irrigation patterns[16]” of individual crops throughout the year and their proportionate share in the total irrigated surface are quite important, therefore, this data has to be additionally accounted for, because certain crops are cultivated and/or irrigated during particular seasons only.

Other aspects to be observed in the assessment of water use and the resulting possible water scarcity include:

- effectiveness of the irrigation system, and
- re-use of water.

4.1.3 Availability of basic data

The following institutions publish data concerning resources and use:

- AQUASTAT is the FAO’s global information system on water and agricultural issues
- CIESIN / Sedac “Center for International Earth Science Information Network”, which is associated to Columbia University's Earth Institute, provides information to scientists of various disciplines
- University of New Hampshire (UNH). Aims include, e.g., research in the field of global changes in water systems and the influence of human activities
- WRI (World Resources Institute) has prepared a Water Resources eAtlas in cooperation with IUCN, IWMI and the Ramsar Convention on Wetlands
- IWMI (International Water Management Institute), is a research center that also works on the management of land and water resources and other topics

For detailed information concerning these institutes, refer to the Appendix (Chapter **Error! Reference source not found.**).

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[13] In its calculation, the FAO refers to the method of Penman-Monteith

[14] http://www.fao.org/nr/water/aquastat/water_use/kcvalues.htm: Crop coefficients for different growing stages

[15] http://www.fao.org/nr/water/aquastat/water_use/index4.stm :
Review of global agricultural water use per country. Crop water requirements

[16] http://www.fao.org/nr/water/aquastat/water_use/croppat.htm : Irrigation cropping patterns

4.2 Indicators and indices

The indices mentioned in Table 3 provide an overview. For more detailed information as well as calculations, refer to Chapter **Error! Reference source not found.** in the Annex)

Table 2 Summary of the indices and comparison of advantages and disadvantages of their application for the certification of biomass

Index	**Author**	**Special features**	**Advantage**	**Disadvantage**	**Applied in**	**Suits project purpose**
Water availability index (WAI)	Meigh et al	availability only, no reference to stress, scarcity		refer to special features	Sri Lanka, Palestine	yes
Water stress index	Hoekstra		simple	possibly too simple	together with GAP 2 model	yes
Water scarcity index	Hoekstra & Mekonnen	reference to water footprint		complicated	Kenya	no
Water scarcity index	Smakthin	accounts for ecological quantities	broadening of approach	difficult to comprehend		?
Water scarcity index	Asheesh	based on water balance	simple		Israel, Palestine	no?
Water scarcity index	Unesco-IHE 2007:	accounts for desalinated water		especially for coastal areas	Study from Japan	yes?
Water poverty index	Sullivan	accounts for socio-economic factors		complicated	Benin, on the Nile	no
Water poverty index	Sullivan Lawrence	accounts for socio-economic factors		complicated		no
Water consumption index	Mendoza et al.	refers to (fresh) water resources of a country	simple		Mexico	no
Vulnerability of water systems	Gleick	establishes relationship between different quantities		complicated, hard to grasp	USA	no
Water Resources Vulnerability Index (WRVI); SEI-Index	SEI Stockholm	ratio between use and resources		complicated		yes
WEI	Calculation acc. to EEA	ratio between water withdrawal and resources	simple			yes

Source: own compilation

4.3 Models

Some of the indices mentioned were tested with the help of computer models for individual countries or regions, and then sometimes transferred to the global scale. The authors recommend using this global data as initial guidance for the definition and acquisition of “areas with water scarcity” (in accordance with Article 18 No. 3 Para. 2 of Directive 2009/28/EC). In addition, a more precise analysis may be necessary on a case-to-case basis that is more specifically matched to the local circumstances and may in turn be based on the corresponding models. Below, please find an overview of a number of models which may be applicable at least in part to the issue under investigation.

Table 3 Summary of models and examples for calculating water availability and indices and comparison of advantages and disadvantages of their application for the certification of biomass

Index	Author	Spatial resolution
WaterGAP 2 Model	Alcamo et al. (2000) University of Kassel	River catchment areas with a resolution of 0.5°
TRIP (Total Runoff Integrating Pathways)	Oki et al 1997	River catchment areas with a resolution of 0.5°
GTOPO30	USGS (United States Geological Survey)	30 arcseconds (approx. 1 km²)
WBM/WTM-Model	Vörösmarty et al. (1991) Univ. New Hamphire	River catchment areas with a resolution of 0.5°

Source: own compilation

5 Recommendation on applicable indicators

The main purpose of the task to be fulfilled is to define criteria and indicators to avoid negative impacts of biomass production on water as a subject of protection both in terms of quantity and quality. Fehrenbach et al. (2008) previously defined the following criteria:

5.2 Water use must be strictly adapted to the regional resources (offer) and account for the needs of other users

5.3 Detrimental emissions to surface water and groundwater are to be kept to a minimum

Similar criteria have also been put forward in the proposals from the Netherlands (Cramer et al. 2007), United Kingdom (DFT 2008) or the Roundtable Sustainable Biofuel (RSB 2008).

For water as a subject of protection, the EU Commission only sets forth reporting requirements in the Renewable Energy Directive. However, it also specifies the requirements on the contents of reports and the indicators as reports shall cover

1. areas where water is scarce
2. measures for the avoidance of excessive (water) consumption
3. measures taken for water protection

The indicators proposed in the present paper are based on the language used in the Renewable Energy Directive for this reason.

5.1 Definition of excessive water consumption and of areas where water is scarce

5.1.1 Regions with scarcity or lack of water

The term “water scarcity” was discussed in detail in Chapter 3.2. Two concepts for quantifying water scarcity are to be emphasized as being essential:

1. The unavailability of the defined water resources required per person per year; a value below 1,700 m³ is referred to as water stress, a value of less than 1,000 m³ means water scarcity (Falkenmark; UNEP 2002).
2. The relation between water use and available water resources (water stress index); if this value exceeds 0.4, severe water stress is to be assumed; between 0.2 and 0.4 is defined as mid water stress, and up to 0.2 as low water stress (Hoekstra 2003; UNEP 2005; WRI)

Both concepts offer specific advantages. For this reason, they are both proposed as possible indicator approaches for the time being. Figure 6 of Chapter 3.2 presented global maps for both approaches according to calculations done at the University of Kassel.

The maps depicted may serve as a sufficient identification of “areas where water is scarce” in a first step. One would have to verify, however, whether or not the resolution with a grid size of 0.5° is sufficiently fine for the task on hand. An optimum resolution was determined to be in the range of 10 km x 10 km (refer to Chapter 5).

In a given case, it may be necessary to collect data concerning the specific local situation. Especially borderline situations require particular attention. These include:

- Areas with high, spatially compact variability (areas showing low stress on the map adjacent to or interlinked with stressed areas, in particular, in situations involving upstream/downstream riparians)
- Cases in which the status of the area may change as a result of additional water use caused by additional biomass cultivation (i.e. where water stress is induced in previously unaffected/slightly affected areas)

The second type of case is extremely complex because in borderline situations, more factors generally exist, such as population growth or climate change contributing to water scarcity or which may aggravate the water situation in the mid term. Since the establishment of irrigated plantations is planned in longer time frames (approx. 10-15 years), however, future developments also have to be accounted for.

5.1.2 Excessive water consumption

In the Renewable Energy Directive, the question of excessive water consumption is linked to the notion of water scarcity. However, the authors are convinced that water should always be protected by using it economically, independent of whether or not an area with water scarcity is involved. Conversely, this link also puts the term "excessive" in a more relative context - depending on the availability/degree of scarcity, excessive use may take place sooner or later.

The following criteria of excessive water consumption are recommended at this point:

1. Primary condition: Water is used through withdrawal, i.e. irrigation or water consumption in a process.
   Conversely, rain-fed water supply of plants is not covered by the notion of water consumption[17]
2. Where fossil groundwater is used, consumption as such is to be considered "excessive" because regeneration does not take place, and sustainability is excluded from the hydrology point of view
3. If (non-fossil) groundwater is used, stricter requirements have to made on the availability (exclusion of scarcity);
   the fact that groundwater is used instead of surface water leads to the assumption that surface water is already scarce
4. Any type of water use has to be accompanied by measures to minimize consumption; for irrigation, especially efficient, resource-saving irrigation techniques and irrigation management are to be applied
   (these types of measures are explicitly subject to reporting under Art. 18 of Directive 2009/28/EC)

5.2 Formulation of indicators to avoid excessive water consumption by biomass production in areas where water is scarce

On the basis of the possible definitions of "excessive water consumption" and "areas where water is scarce" outlined above a scheme will be provided below that can be used to examine the presence of these notions using indicators or a combination of indicators. This approach is designed to comply with the reporting requirements under

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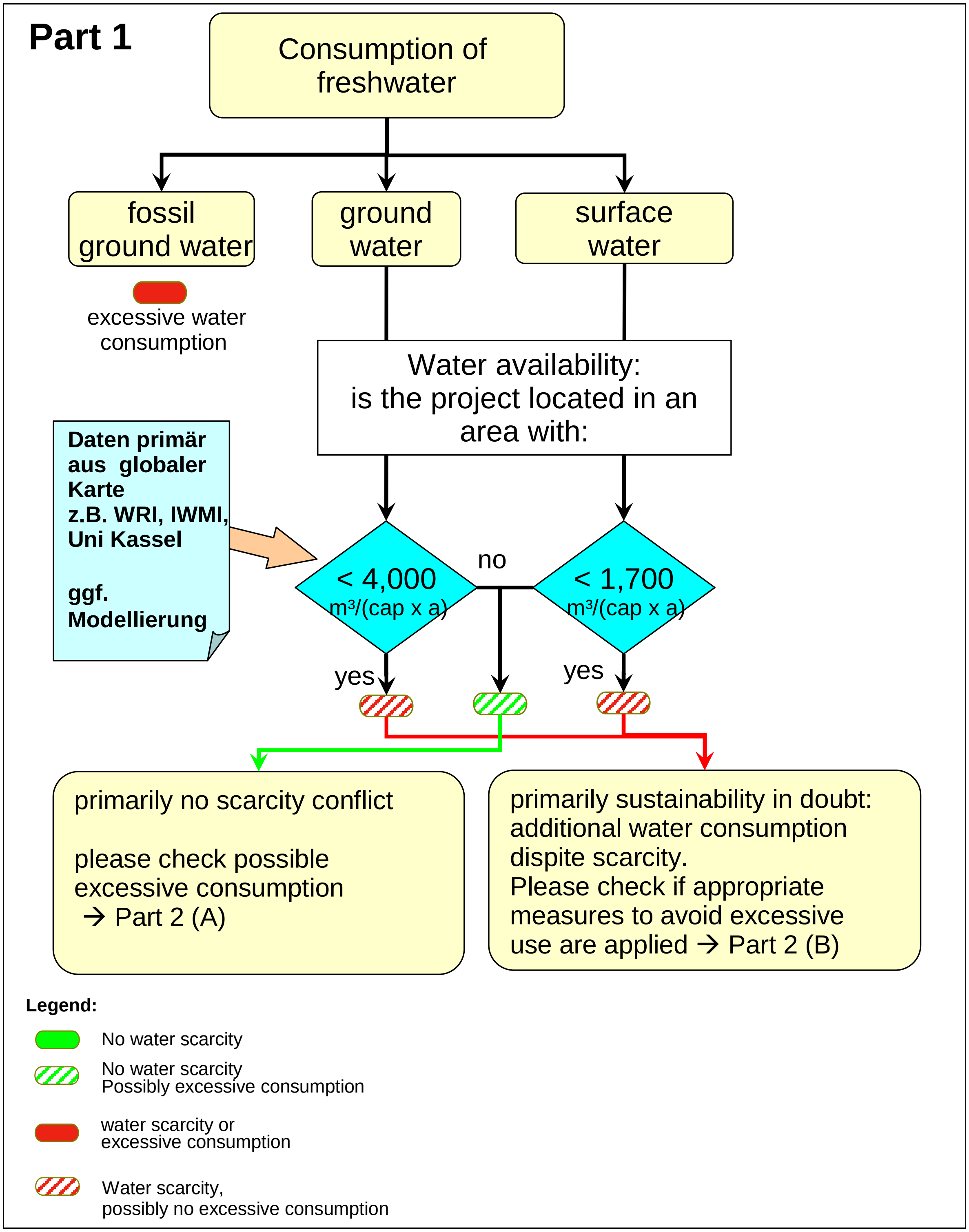
[17] Special cases in which the type of crop alone may have negative effects on hydrology even without irrigation (e.g. eucalyptus plantations or KUP) have been excepted for the time being and require more profound investigations.

Art. 18 of Directive 2009/28/EC as well as the specific sustainability criteria regarding water and bioenergy. The following graduated method will be useful in this context:

☐ No water consumption takes place	→	no conflict with sustainability; this must be ensured by the report
☐ Water consumption takes place, area where water is not scarce	→	sustainability criteria are met if excessive consumption is prevented by suitable measures; report on measures (not compulsory under the Directive because water is not scarce)
☐ Water consumption takes place, area where water is scarce	→	sustainability is questionable, assessment whether consumption is excessive, and whether suitable measures have been implemented; if scarcity is striking, the measures must be even more severe report on measures and guaranteed prevention of excessive consumption

Figure *7* to Figure 9 show charts that may serve to verify excessive water consumption in areas where water is scarce and on the basis of the indicators proposed.

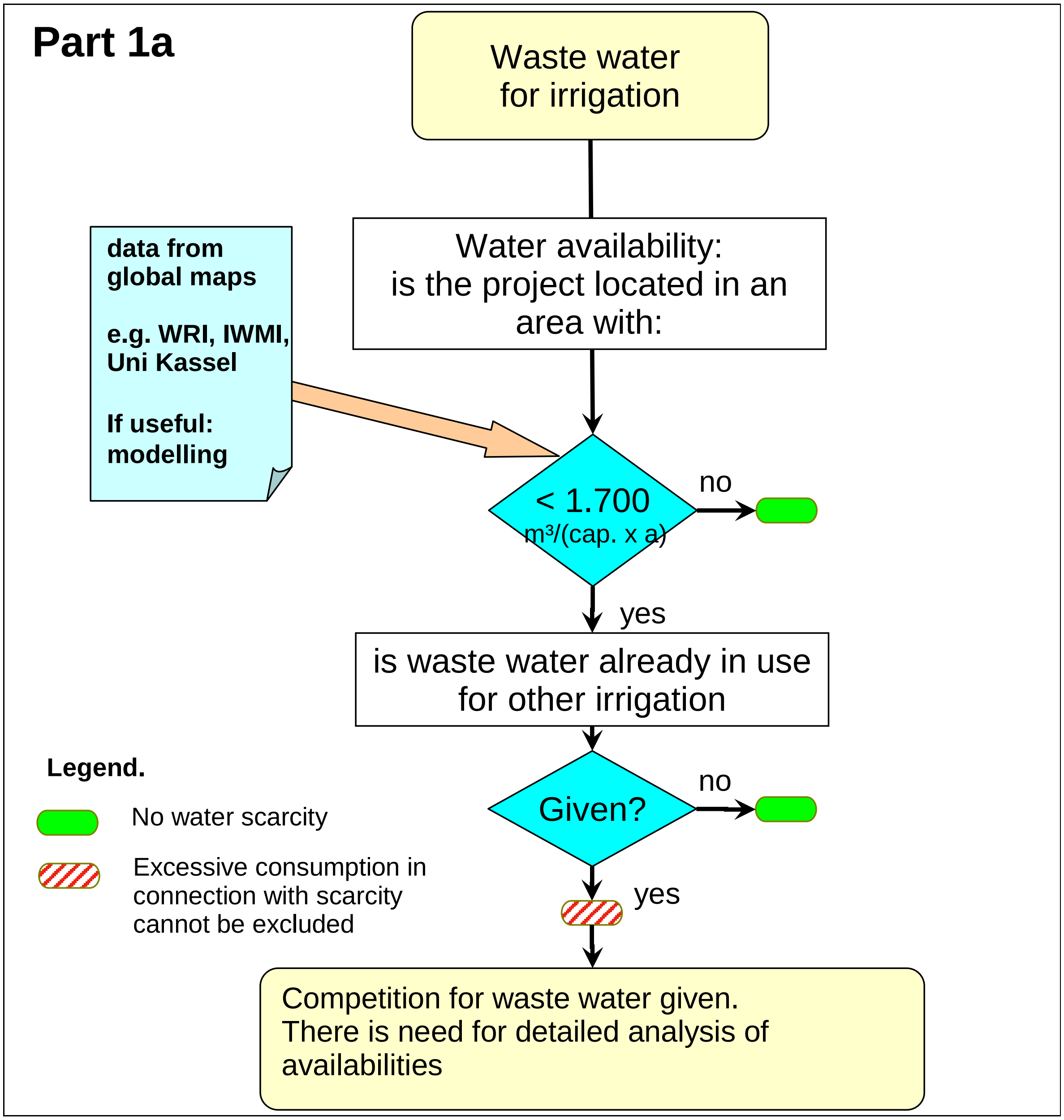
Figure 7 Test chart "Excessive water consumption in areas where water is scarce" – Part 1



Source: own chart

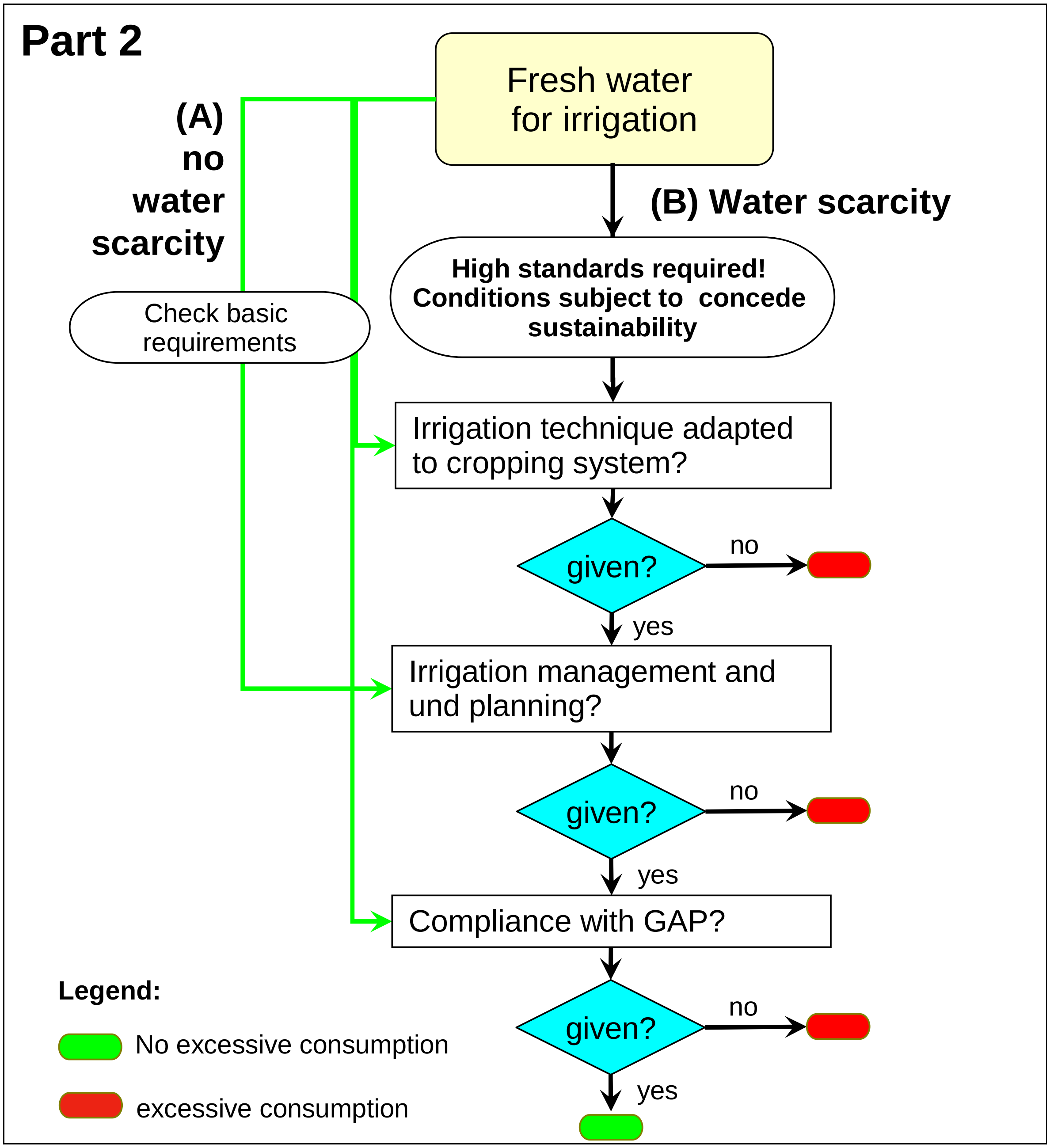
Figure 8 shows the special case of wastewater irrigation. In general, one would initially assume that the use of this kind of resource does not give rise to or aggravate scarcity issues. However, this may be the case if wastewater resources have previously been used for irrigation (for ongoing production of food or other agricultural produce). In these cases, a more detailed analysis of the conditions of local water use will have to be carried out to identify the risk of increasing water scarcity.

Figure 8 Test chart "Excessive water consumption in areas where water is scarce" – Part 1a (wastewater irrigation)



Source: own chart

Figure 9 Test chart "Excessive water consumption in areas where water is scarce" – Part 2



Source: own chart

5.3 Formulation of indicators for preventing negative impacts on water quality

5.3.1 Requirements on the quality of agricultural production

These requirements are basically derived from the rules listed in Chapter **Error! Reference source not found.** (mainly “Cross Compliance”). The proof of compliance with the principles of *good agricultural and ecological conditions* (GAEC) and the *statutory management requirements (SMR)* should provide sufficient indicators for ensuring compliance with the quality requirements of this aspect.

If the biomass is produced outside the scope of EU legislation, proof of compliance with the GAP requirements of the FAO (2003a) may also be requested. The test chart on “excessive water consumption” has already taken this into account, because by making reference to GAP, both quality and quantity requirements are complied with (refer to Figure 9).

5.3.2 Quality requirements on wastewater irrigation

Wastewater use is to be examined not only under the aspect of “water consumption” (refer to Figure 8), but mainly with respect to possible pollution. If wastewater is used for irrigation, it most be proven that the wastewater used does not exceed the statutory (national or international) limit values. These quality requirements on wastewater must be identified, evidenced and documented on a case-to-case basis (according to type of wastewater).

Wastewater also contains nutrients such as nitrates and phosphates. These nutrients must also be accounted for when determining the indicator of fertilization according to need discussed in the previous section.

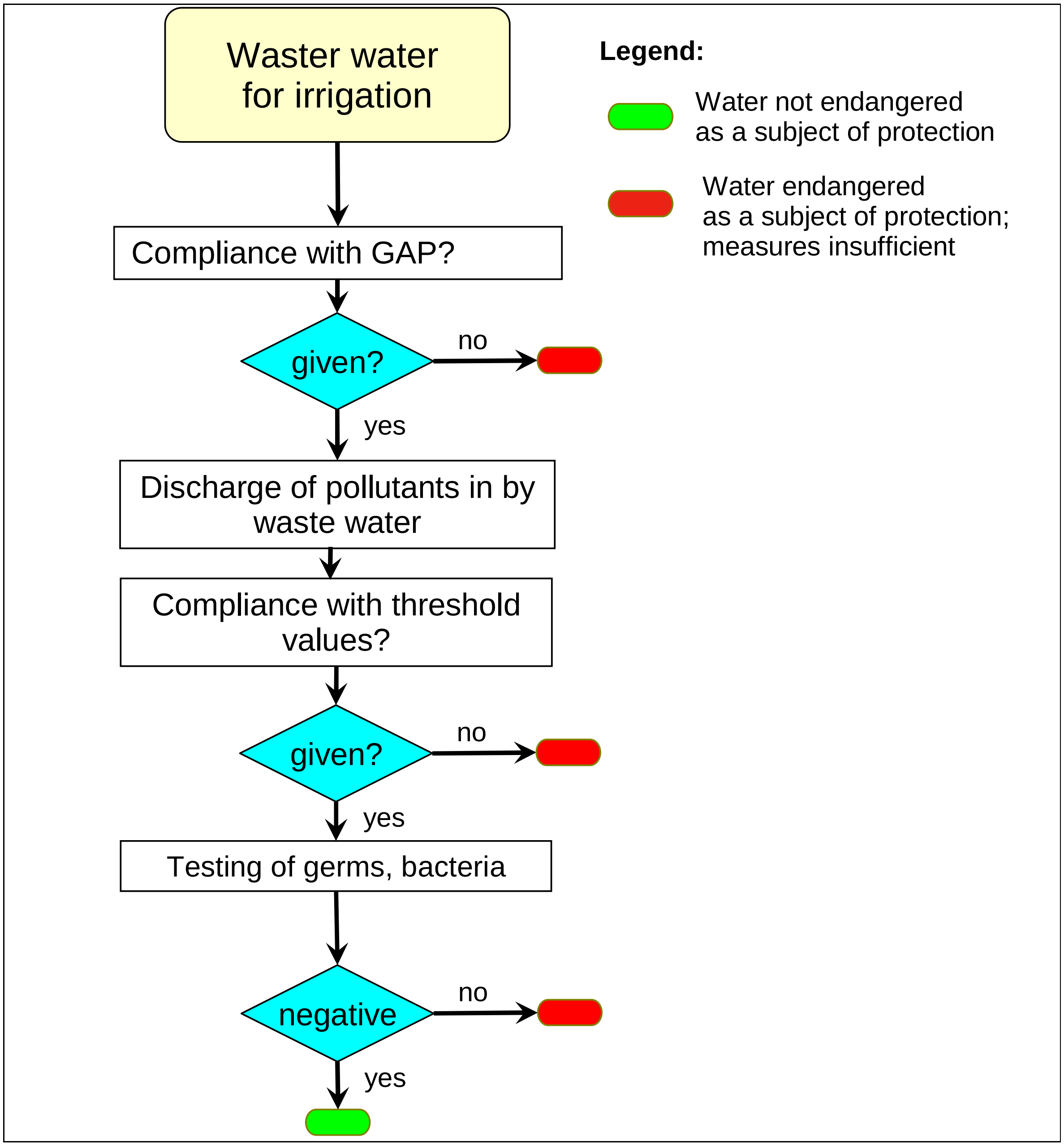
Figure 10shows a test chart concerning the effects of wastewater irrigation on the water quality.

5.3.3 Quality requirements on process wastewater

Figure 11shows a test chart concerning the effects of process wastewater emission on the water quality.

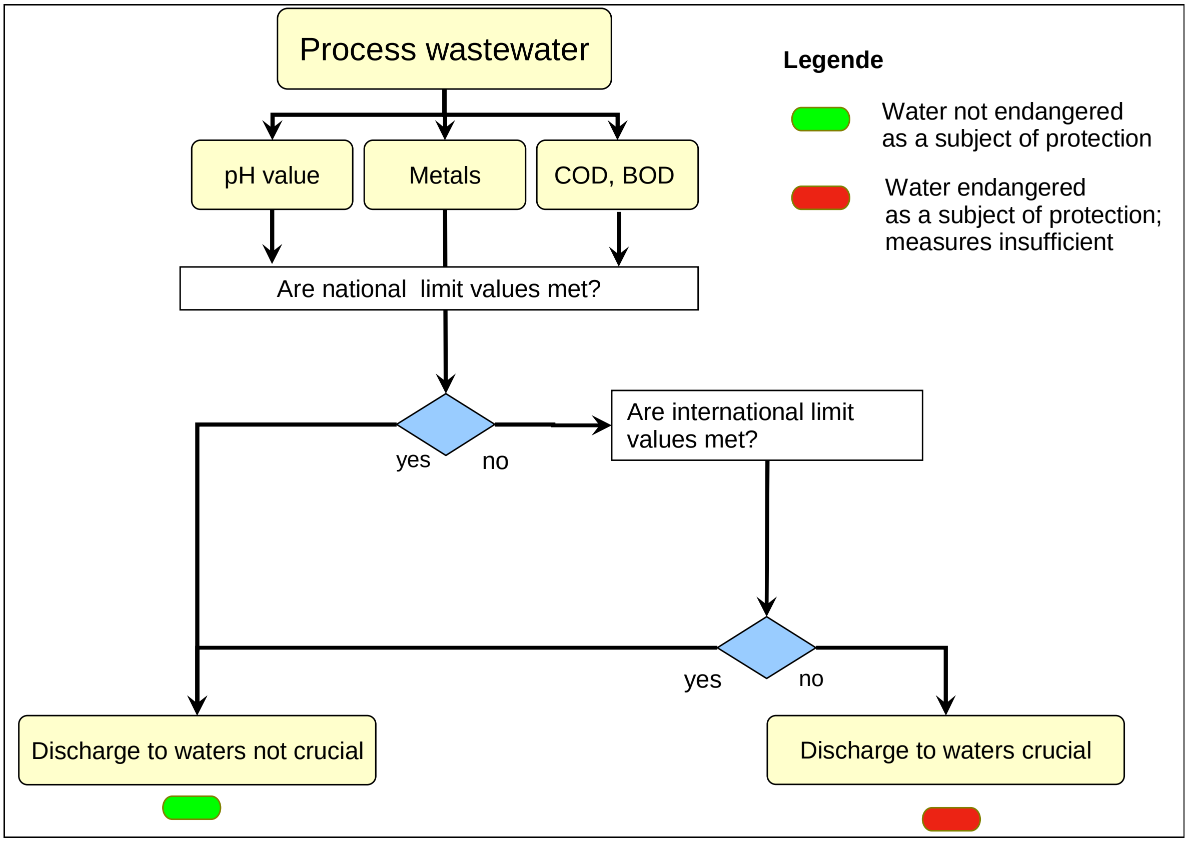
Annex **Error! Reference source not found.** contains a number of examples of wastewater limit values. Annexes **Error! Reference source not found.** and **Error! Reference source not found.** contain examples of the pollutant contents of various kinds of wastewater generated by bioenergy production processes.

Figure 10 Test chart concerning the “effects of wastewater irrigation on the water quality”.



Source: own chart

Figure 11 Test chart concerning the "effects of process wastewater emissions on the water quality".



Source: own chart

5.4 Open aspects

The applicable indicators or indicator models proposed in the present report with primary reference to the requirements of Directive 2009/28/EC and evidence of their compliance must be examined for their practical application.

It is assumed that a major portion of biomass production projects can be assessed with sufficient accuracy on the basis of the global data obtainable on water availability with a comparatively good regional resolution (IWMI, WaterGap etc.). It is currently unclear whether sufficient approaches can be developed which also account for the numerous borderline situations. This refers to cases in which, e.g.,

- water is not yet scarce, although an additional irrigation project could cause such scarcity on the basis of the quantities involved. In such a case, one would have to find out in how far the biomass project would be the decisive factor
- a particularly large irrigation project would have to be categorically assessed as being unsustainable although a very well adapted irrigation technique and design and well adapted irrigation management are applied, because water is already scarce
- an irrigation project would develop general water supply opportunities, thus mitigating the *economic* water scarcity of the population

Furthermore, one would have to ask,

- whether monitoring using bioindicators or biodiversity would be able to prove negative changes in the mid term if suitable bioindicators exist
- in which cases rain-fed farming can have negative impacts on hydrology. The study of NABU (2008) should be mentioned again at this point which assumes a negative impact of poplars and willows on the water balance because these trees have a higher water demand than other species. The influence on the water balance depends on a number of different factors, such as proximity to wetlands, the size of the area, precipitation, soil properties, etc. According to this study, low annual precipitation <600mm and the water storage capability of the soil are decisive factors in this context

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