

# **Sectoral Impact Assessment**

Roger E. Rivero Vega

# Introduction...1

- Climate change will negatively impact many different sectors and socioeconomic activities.
- Identified sectors that will be affected by climate change are not equally related to the magnitude and seasonality of climate variables.
- The strength of relationships between relevant climate variables and parameters characterizing the actual behavior of those sectors are also different among them and some will be more affected than others.

**What sectors could be affected by climate change?**

# Introduction... 2

Sectors that will be impacted by climate change include:

- **Water resources**
- **Agriculture and food production in general**
- Coastal and marine ecosystems
- Human settlements
- Human health
- Energy
- Tourism
- Others?

# Impact Models 1

- In order to estimate qualitatively/quantitatively what kind of impacts and what will be their magnitude on a given sector, **we must have some conceptual or mathematical model relating values of climate variables with relevant sector parameters.**
- This kind of **tool** will be designated here as an **impact model**. Even if it is not easy to explain here, **impacts models in agriculture are driven by climate variables and its behavior in time.**

# Impact Models 2

- Impact models can be of very different kinds, in large part depending of the sector or the relevant sector parameters we are interested in.
- To bring this aspect to Earth, we'll be discussing here **the agricultural sector** because it one of the more complex sectors with more **available impact models**.

# Agricultural Models

- **Agricultural models differ from the more common statistical models because they actually model ecological and physiological processes inherent to plants, animals and ecosystems in general.**
- Such processes are controlled not only by genetic but by **the abiotic environment**, including of course physical conditions representing the day to day weather changes and daily value of climate variables.
- Agricultural activities and models are related to many climate variables.

**Where do these climate variables come from?**

# **No assessment is possible without adequate climate information... 1**

**Past and actual values of climate variables** needed in order to run a sector impact model **come from** historical climate datasets built by **National Meteorological Services**.

**Some** complex and detailed impact **models require** **daily datasets**, that's the case of crops, but **others could need only monthly mean data and even annual mean data**.

# **No assessment is possible without adequate climate information... 2**

**The structure of the necessary climate datasets  
is conditioned by the needs of the chosen  
impact model.**

**The reverse is also true because the chosen  
impact model is conditioned by the nature of  
the available climate dataset.**



# **No assessment is possible without adequate climate information... 2**

**If you don't have a daily climate dataset but only a monthly means climate dataset you won't be able to use impact models contained in DSSAT 4.5, but you'll be able to use crop model WOFOST 7.1.2.**

# **No assessment is possible without adequate climate information... 3**

**Future expected values** for every relevant climate variable are not observed values... they **must be obtained creating climate change scenarios for any future date.**

Even if **future climate change scenarios** may be constructed in different ways, **most internally consistent scenarios** are those **based on Global and Regional Climate Models runs.**

# Agricultural Models... again

Some agricultural models are:

- Crop models such as **WOFOST 7.1.2**, **CSM** model embedded in **DSSAT 4.5**, **Aqua Crop 3.1 Plus** and many others.
- **JABOWA** model simulating forests
- **SPUR 2.2** simulating cattle/pastures interactions
- **CENTURY 4.5** simulating biogeochemical cycles and organic matter decay in soils (S, N, P).

# What do crop models do 1?

A crop model is a very complex tool based on knowledge from many sciences including astronomy, physical climatology, plant physiology, soil science, ecology and others.

A crop model solves:

- **The radiation balance equation**
- **The energy balance equation**
- **The water balance equation**
- **The biomass balance equation**

# What do crop models do 2?

The biomass balance equation:

**Daily increase in net biomass = Daily gross photosynthesis – rate of respiration losses**

$$dB_n / dt = dB_g / dt - r$$

Then the model distributes the daily increase of biomass among different plant organs according to the phenological stage of the crop. A process known as **partitioning of assimilates** or photosynthates.

# What do crop models do 2?

The process of growth and developing proceeds continuously until final product to be harvested reaches maturity.

Calculation of  $dBg/dt$  is a very sophisticated procedure... the simplicity of the biomass balance equation is deceiving...!!

# Calculation of yields...

There are different kinds of yields...

**Potential yields** depend only on plant genetic characteristics, global solar radiation and temperature.

Additionally **water-limited yields** also depend on water availability for crop growth and development (precipitation, irrigation and soil water content).

**Nutrient-limited yields** also depend on nitrogen, phosphorous and potassium availability in soil.

# Classification of plants... 1

Plants are classified according to their **photosynthetic pathway** in **C3** and **C4** plants. Both of these types can also be classified as **adapted to cool climates** or **to warm climates**.

Using solar radiation C3 plants capture  $\text{CO}_2$  from the atmosphere synthesizing a **three-carbon atoms molecule**. C4 plants do the same but forming a **four-carbon atoms molecule**.

**C3** and **C4** plants differ considerably in their responses to climate conditions and changes.



# Classification of plants... 2

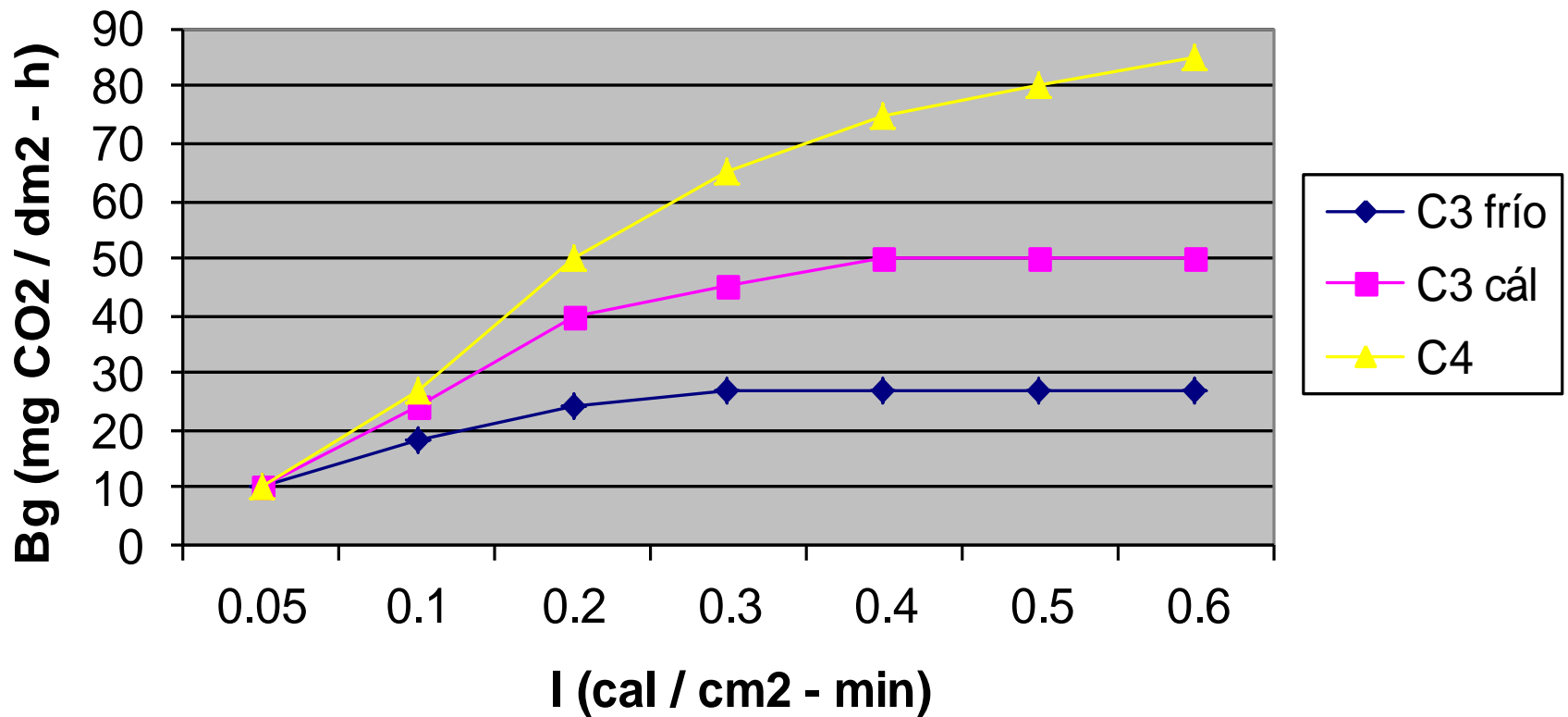
Parameter	Type 1	Type 2	Type 3	Type 4
Pathway	C3 c	C3 w	C4 c	C4 w
P maximum	20 – 30	40 – 50	70 – 100	70 – 100
ISAT	0.2 - 0.6	0.3 - 0.8	> 1.0	> 1.0
T optimum	15 – 20	25 – 30	20 – 30	30 – 35
Crops	Wheat, potato	Soybean, Sorghum, rice, cassava, sweet potato	maize	Maize, millet, sugarcane

# **A very brief description**

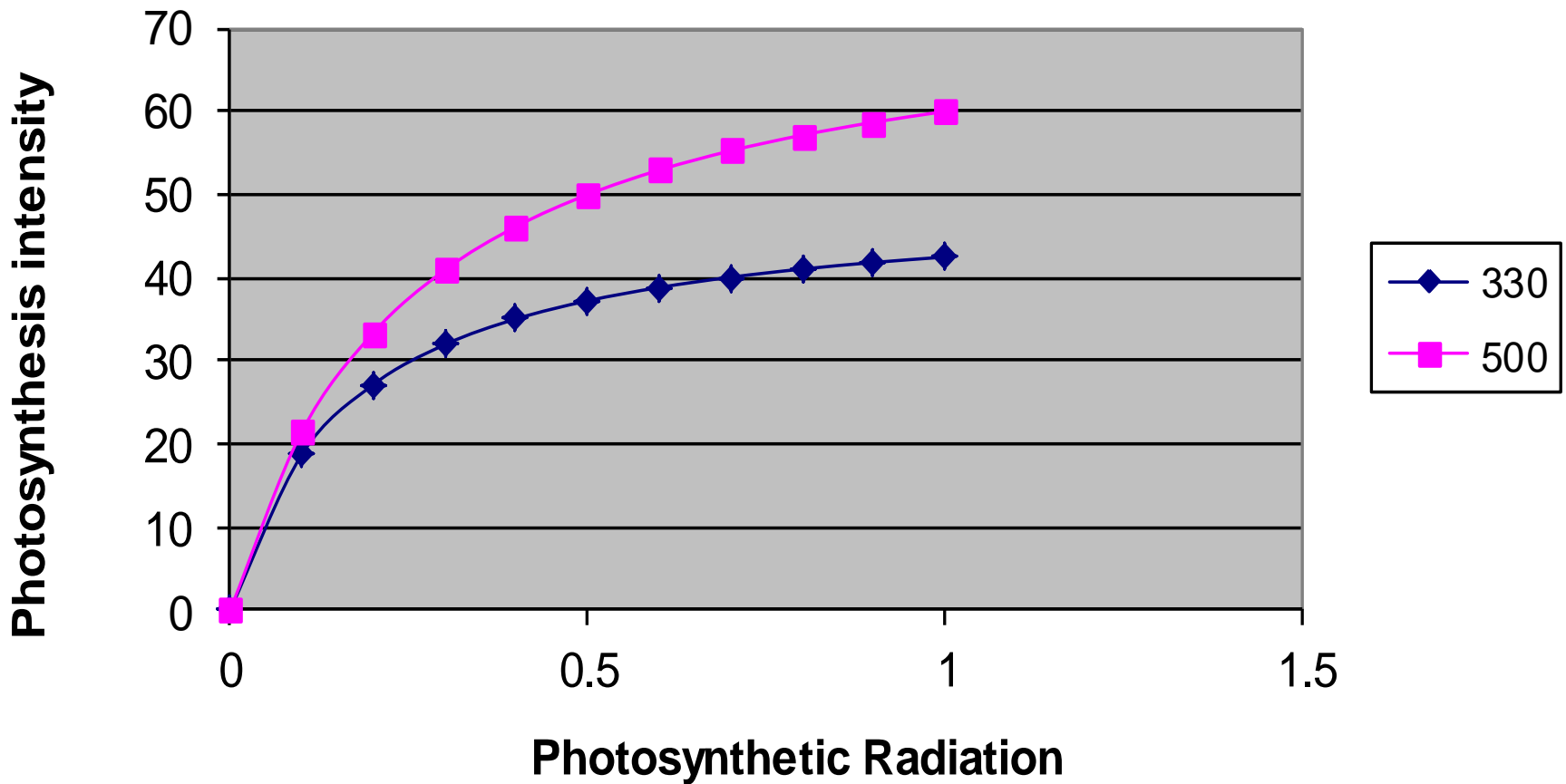
Using solar radiation, water and CO<sub>2</sub> (gross) **photosynthesis produces sugars** and releases oxygen. **Part of that sugar is burnt** to obtain additional energy. This **energy plus remaining sugar and N, P, K taken from the soil** are then used for synthesizing **complex carbohydrates, proteins and fatty compounds.**

In this machine of life **plants are primary producers...** their biomass constitutes **the first link of the trophic chain.**

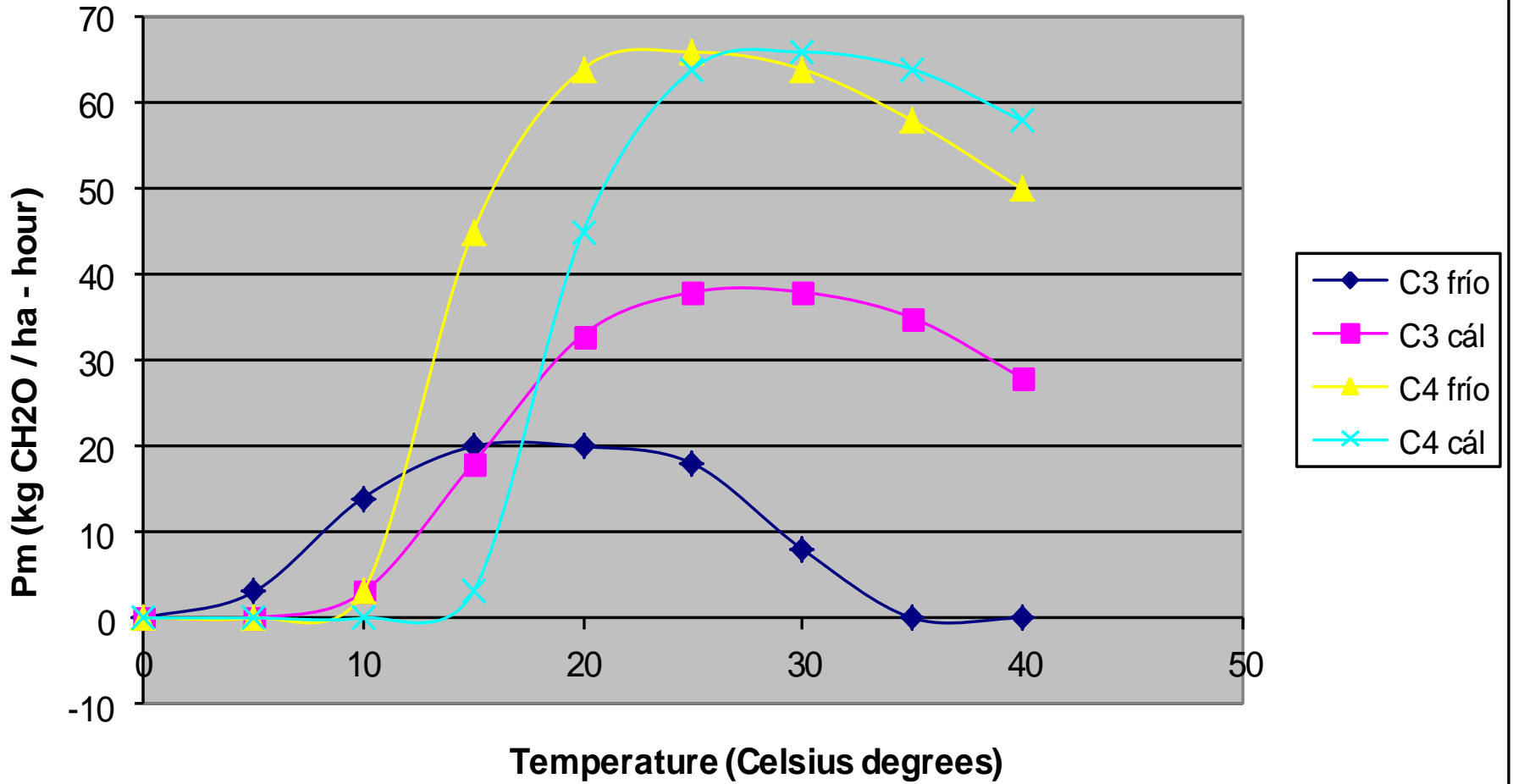
# Photosynthesis response to the intensity of photosynthetic radiation



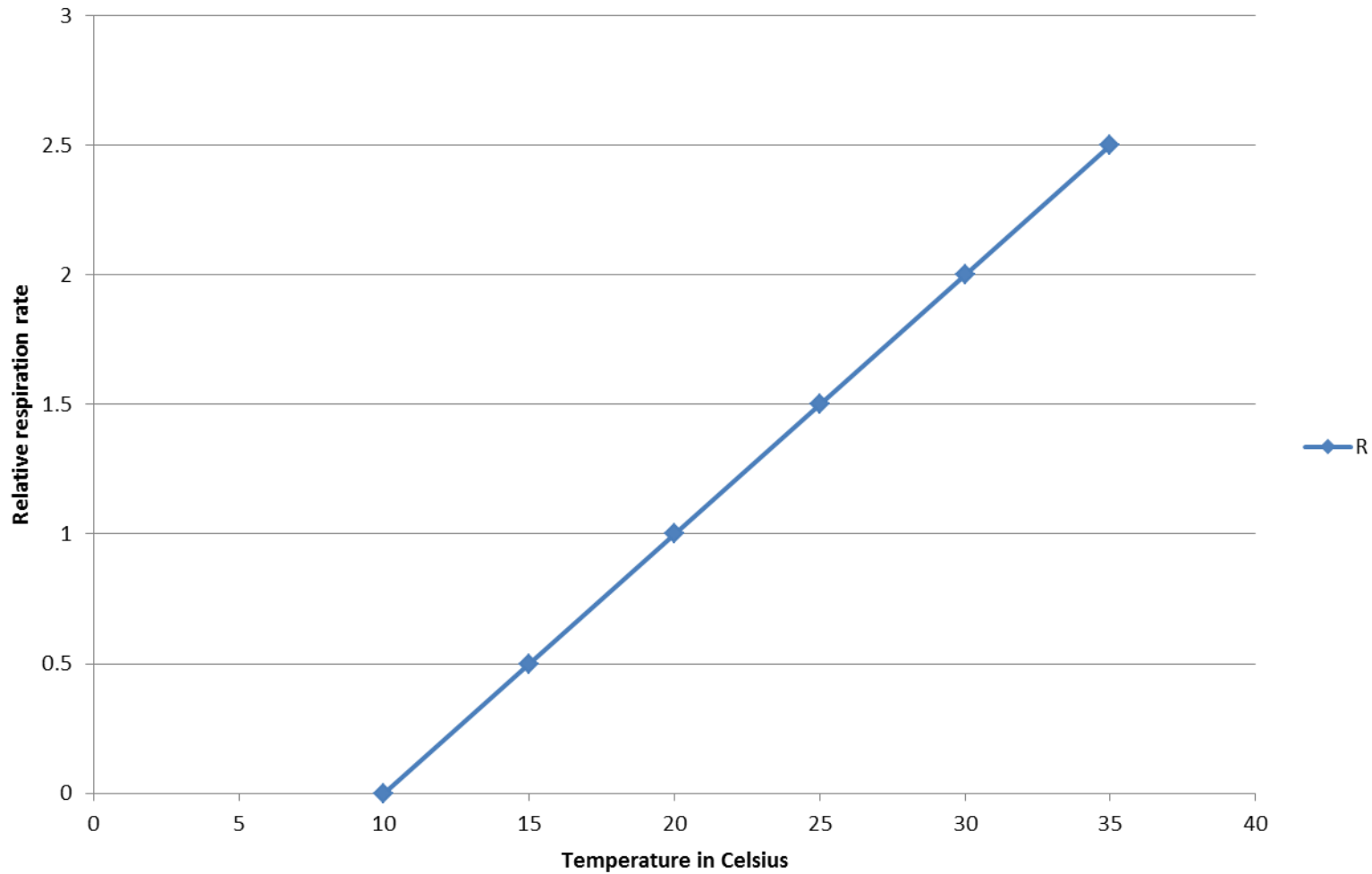
# Photosynthesis intensity dependence on radiation for two different atmospheric concentrations of CO<sub>2</sub>. (the CO<sub>2</sub> fertilization effect)



# Temperature dependence of maximum gross photosynthesis



## Respiration intensity dependence on temperature



# Climate Input Data Revisited

A minimum requirement of climate input data for these kinds of models consist in daily values of:

- **CO<sub>2</sub> atmospheric concentration**
- **Global solar radiation**
- **Maximum and Minimum Temperatures**
- **Precipitation**
- **Water vapor pressure**
- **Wind speed**

# Where do these input values come from?

In making an impact assessment you need to first run your impact models with your **baseline climate data**. This climate dataset is provided by time series of climate variables **actually observed in your meteorological stations network**.

Then you must run your impact models with **climate data generated in the making of the climate change scenarios**.



# The assessment itself...

**Impacts from climate change are derived by** comparing impact model runs made **with climate data projections** for a **future date** with impact model runs made with values corresponding **to the actual observed reference climate**.

**Adaptation options are assessed the same way** using **climate data from the scenarios** but including the modification you are proposing as an adaptation option.

Let's say, going from rainfed to irrigated agriculture, changing planting dates or any other adaptation option that is being assessed **as a countermeasure to some detected negative impact of climate change**.

# Another Sector... 1

Water resources sector requires us to solve the **water balance equation**. A daily or monthly water balance model could be as “**simple**” as:

$$W2 = P + W1 - E - S$$

**W1, W2** – soil water content at the beginning and end of a given time period

**P** – precipitation

**E** – real evapotranspiration

**S** - runoff

## Another Sector... 2

It seems at first sight that **only precipitation values** could be provided here by climate sciences... **but it is not true.** Using **solar radiation, water vapor pressure, temperature and wind speed**, climate science allows us to estimate **real evapotranspiration and runoff from first principles.**

A **sequential solution process** makes **the initial condition W1 irrelevant...** the system forgets its initial state in 12-24 time steps... !

# Final Remarks

Sector assessments **not using climate change scenarios** are **usually meaningless** and even harmful.

Sector assessments **not using validated impact models** could be **no more than wishful thinking.**

**Expertise** in sector behavior **in actual climate** is **widely available...** that kind of expertise **in expected future climate conditions** might not exist yet... !

# Recommended Literature

The scientific basic knowledge necessary to fully understand agroclimatic modeling can be seen at

<http://www.agrometeorology.org>

Rivero, R. E. (2008): **Workbook of Climate Change Impacts Assessments in Agriculture: Basic Knowledge, Methodologies and Tools**. CCCCC / INSMET / Commonwealth Secretariat, 148 pp. ISBN 978-976-95260-1-3 (PBK) EAN 9789769526013

Rivero, R. E. (2010): **A Set of Logical Steps in Order to Make an Assessment of Climate Change Impacts on Agriculture**, 15 pp.