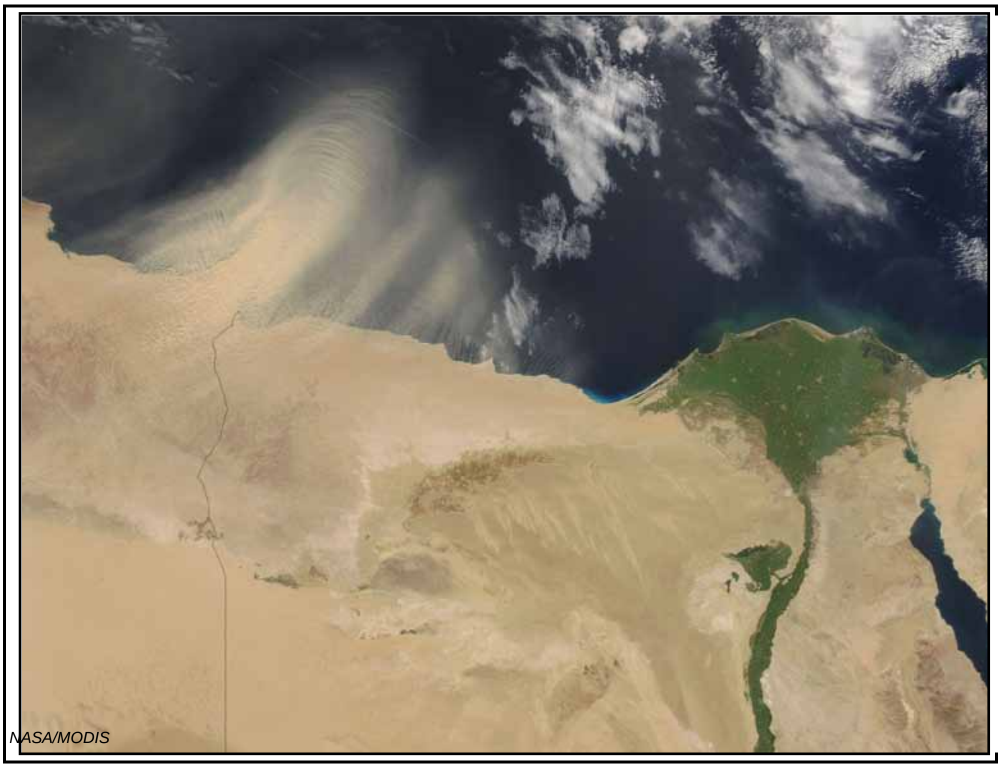
French-Egyptian project
"*Sustainable Management of Adverse Impacts on Farming and Soil Ecosystem Associated with Long Term Use of Low Quality Irrigation Water*"

Progress Report



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1. General framework

In July 2010, a joint research project was filed by Erik BRAUDEAU (Institute of Research for Development, IRD) and Alaa M. ZAGHLOUL (National Research Centre, NRC) in response to the first French-Egyptian call for proposals launched by IRD/AIRD (Agency of Inter-institutional Research for Development) and STDF (Science and Technology Development Fund).

The submitted proposal was separately evaluated by IRD/AIRD and STDF experts. A positive evaluation was announced in late March 2011 along with eight other projects also accepted among 52 submitted proposals. Its duration will be two years after the official starting date. Its title is "*Sustainable Management of Adverse Impacts on Farming and Soil Ecosystem Associated with Long Term Use of Low Quality Irrigation Water*" (BRAUDEAU and ZAGHLOUL, 2010). Funding for each Egyptian and French partner is 148 kEuros while 193.7 kEuros was requested.

Following a meeting held at the headquarters of IRD (Marseille, France) in early June 2011, the head of project management in AIRD, Pierre SOLER, has decided to fund the project implementation at 20 kEuros. The budget office has established the amount only in February 2012 after an urgent request. Furthermore, no research agreement was signed between IRD/AIRD and STDF.

In July 2011, Erik BRAUDEAU is retired and was replaced by Marc LOINTIER (IRD). **IRD/AIRD-STDF project officially started September 11th, 2011 and will be completed by September 10th, 2013**. A preliminary literature review has been conducted by two project partners (ZAGHLOUL et al., 2011) and delivered in December 2011 along with a first progress report (ZAGHLOUL, 2011). In September 2012, a second progress report was written by the Egyptian team (ZAGHLOUL, 2012).

2. Scientific framework

The main objective of the project is to monitor the adverse impacts of applying low quality irrigation water in Egypt (Nile delta) as well as to innovate proper technologies to limit these adverse impacts on farming and soil ecosystem (BRAUDEAU and ZAGHLOUL, 2010).

The specific objectives are:
- using best management practices to improve both farming and soil ecosystem with computer modeling;
- improving planning and management procedures to satisfy future demands in Egypt depending on better use and efficiency of present water resources;
- assessing the long term adverse impacts on farming and soil ecosystem.

Five study sites were selected by the Egyptian side depending on the type of irrigation water: Abu-Rawash and Zenin (Northwest and West Cairo) with waste water; Kafr el-Sheikh (North Nile delta) with drainage water; Tanash (North Cairo) with natural Nile water; El-Salam (North Sinai) with mixed water (waste, drainage and Nile waters).

The scientific project is divided into four work packages (WP) according to the diagram in Figure 1. IRD is primarily involved in WP2 (Bioclimatology) and WP4 (Hydrostructural Pedology). WP3 (Geographic Information System) involves jointly IRD and NRC teams.

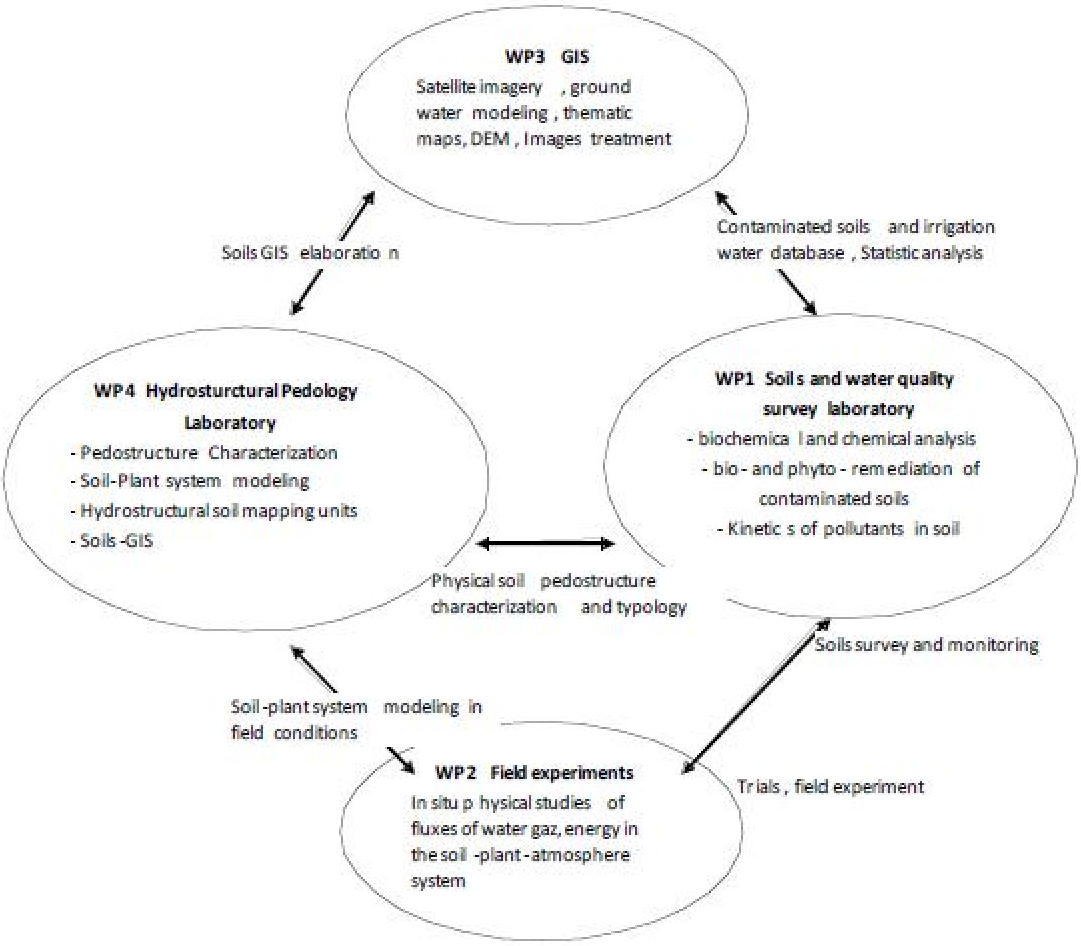


Figure 1. Diagram describing the relationship between the workpackages

3. Mission objectives

Marc LOINTIER, principal investigator (PI) of IRD/AIRD side conducted a preliminary mission from September 26th to October 1st 2011 (LOINTIER, 2011). This mission was a first contact with the Egyptian partner and the opportunity to visit two study sites (North Sinai and Abu-Rawash near Cairo). As hydrologist specialized in remote sensing, Marc LOINTIER visited the centre of the National Authority for Remote Sensing and Space Sciences (NARSS) in Cairo and was especially interested in the management of surface waters during field visits including the North Sinai Development Project. Everything related to soil and soil-water-plant relationships was not covered and therefore implied a second mission which was urgently asked Jean-Pierre MONTOROI (soil scientist) and Georges NIZINSKI (bioclimatologist). It was carried out from 10 to 19 November, 2011. As funding granted by IRD/AIRD in 2011 were not yet available, these first two missions were funded by Christian VALENTIN, the Deputy Director of the Joint Research Unit (JRU) so-called "*BIOEMCO*".

Furthermore, from November 28th to December 2nd, 2011, a training seminar on "*Hydrostructural Pedology*" was organized by Mohamed HACHICHA (INRGREF, Tunis, Tunisia), Erik BRAUDEAU (Qeeri, Doha, Qatar) and Jean-Pierre MONTOROI (IRD, Bondy, France). This seminar was held in Tunis and was funded by a "*Structuring Thematic Action*" from IRD (HACHICHA et al, 2011). It was attended by researchers and teacher-researchers from West Africa (Burkina Faso, Senegal), North Africa (Morocco, Tunisia) and Middle East (Egypt, Qatar). For Egypt, our colleague from NRC and principal investigation of the AIRD-STDF project, Alaa ZAGHLOUL, was present as well as Marc LOINTIER and Georges NIZINSKI for the French side.

During a Franco-Egyptian discussion sidelines of the seminar, it was decided to urgently start field operations by a mission from the beginning of 2012. Jean-Pierre MONTOROI and Georges NIZINSKI were again involved. The provision of 20 keuros granted in 2011 by the IRD/AIRD was requested in late February so that a mission can be implemented from 3 to 18 March, 2012.

Both missions carried out by Jean-Pierre MONTOROI and Georges NIZINSKI in November 2011 and March 2012 are described in this report and are a continuation of the first mission performed by Marc LOINTIER. The main objectives are:

. Know the Egyptian partnership (NRC) and the local scientific context;
. Present the project to the IRD Representation in Egypt and understand the local constraints for implementation;
. Visit the selected study sites of the project;
. GPS locate study sites and soil sampling locations already made by the Egyptian team for laboratory analysis;
. Perform a soil expertise by collecting soil information (maps, physico-chemical analyses...) in order to prepar a further soil sampling mission;
. Collect past and actual bioclimatological data and select a site to acquire monitored measurements;
. Prepare future field and laboratory experiments.

The schedule of the two missions are displayed in Appendice 11a.

4. Relationship with NRC and other agencies

The French contribution of the project is IRD/AIRD through the JRU "*BIOEMCO*" and its laboratory of "*Hydrostructural Pedology*" located in the IRD Northern France centre of Bondy. The Egyptian institutional partner, who is NRC, is the largest multidisciplinary centre for research and development in Egypt devoted to basic and applied research in the areas of major interest. It has an important scientific and technological infrastructure employing approximately 4,850 people. It consists of 14 divisions and 111 departments covering the major areas of industry, health, environment, agriculture, basic sciences and engineering. The NRC is headed by a president with ministerial status, assisted by two vice-presidents, one for research and one for Technical Affairs.

For each mission, a meeting was held with partners from NRC (Dokki, Cairo) to exchange information on the project IRD/AIRD-STDF and focus on the work ahead. It was also an opportunity to visit the NRC laboratories, including those of the "*Soils and Water Use*"Department, and meet Egyptian researchers.

NRC entrance in Dokki, Cairo

NRC logo

A visit of "*Soils, Water and Environment Research Institute*" (SWERI) from Agricultural Research Center (ARC at Giza, Cairo), Ministry of Agriculture and Land Reclamation, was organized by Dr. Rafat Ramadan ALI on March 13th 2012. A presentation of the on-going work was performed namely the soil survey of Egypt using GIS. It was an opportunity to discuss with Dr. Eng. Mohamed ISMAIL and Dr. Rafaat Kamal YACOUB (Soil Survey and Classification Research Department, Remote Sensing and GIS Unit).

SWERI entrance in Giza, Cairo

5. IRD context in Egypt

During the two missions, a meeting was scheduled in the presence of Saïd JABBOURI, IRD representative in Egypt, and Amro Fayez BAHGAT, administrative assistant. The meetings took place on 13th November 2011 and 7th March 2012 at the IRD representation which is located at Maadi, south of Cairo.

These meetings were main objectives:
. to appear in person;
. discuss the modalities of intervention on the premises that can offer support IRD representation in terms of logistics;
. update the information about the IRD/AIRD-STDF project.

It is assumed that an IRD vehicle can be requested for field trips, as needed. The building of the IRD Representation makes available the facilities to work well in complement of those offered by the partner. Temporary storage of material is possible. Concerns have been raised by missionaries about the availability of financial amount allocated by IRD/AIRD to the project.

It is recommended to follow the instructions of the French Ministry of Foreign and European Affairs for trips in Egypt, particularly in the northern Sinai. Our study site of El-Salam, which is located in this region, is declared in "*orange*" area. It is subject to administrative restrictions that should be followed.

IRD entrance in Maadi, Cairo

6. Field visit of the selected study sites

The WP3 workpackage has the objective to spatialize the soil formation using different methods such as remote sensing, geophysics, geographic information system (GIS)… and include the new paradigm in Pedology described by BRAUDEAU and MOHTAR (2009).

Before the 2011 mission, Jean-Pierre MONTOROI met in Paris October 28, 2011 Michel DABAS, Director of the "*Geocarta*" company for possible involvement in the project. The company is specialized in soil survey using high frequency geophysics. Depending on the funding received from the project, a quotation of the expertise costs according to the expected deliveries should be requested.

6.1. Location of the study sites

During the mission done in 2011, the visits of two sites had been organized by Alaa ZAGHLOUL. For the site of El-Salam located in North Sinai, special permission must be sought from the Egyptian Government. The request has not officially been answered before and during the mission making it impossible the planned trip. Only the visit of Abu Rawash site has been done.

During the mission performed in 2012, the five project sites were visited (Figure 2). The El-Salam site has a particularity because it includes three farms which are distributed within a transition zone from the Sinai desert to the Nile delta.

Figure 2. Location of the five study sites (satellite imagery from 100 km above ground level)

Table I shows the geographic coordinates of the seven farms that have been estimated through Google Earth imagery. These sites are represented by either a building (El-Salam and Kafr el-Sheikh), or by a characteristic place (Abu Rawash, Zenin and Tanash). The distance from Cairo is added.

Table I. Estimated geographic coordinates of the selected study sites in Datum WGS 1984 (from Google Earth Imagery)

Governorate	Site	Distance from Cairc	Geographic coordinates	
			North	East
Gizeh	Zenin Farm	7	30°02'30.17"N	31°10'00.05"E
Gizeh	Tanash Farm	10	30°07'44.09"N	31°11'32.73"E
Gizeh	Abu Rawash Farm	17	30°04'22.59"N	31°03'41.81"E
Ismaïlia	El Salam Farm 1	155	30°55'33.58"N	32°29'15.73"E
Ismaïlia	El Salam Farm 2	155	30°56'17.36"N	32°28'57.60"E
Port-Saïd	El Salam Farm 3	155	30°58'31.47"N	32°27'01.22"E
Kafr el-Sheikh	Kafr el-Sheikh Farm	160	31°28'31.61"N	31°11'38.89"E

6.2. Location of soil sampling

Table II shows, for each selected farm, the GPS (Global Positioning System) measurements of the soil sampling places. The data were recorded using a Garmin eTrex® 20 and are presented in geographic coordinates and their projections in UTM coordinates (Universal Transect Mercator). The soil sampling was done by Egyptian colleagues before the 2012 mission except Zenin and Tanash farms which were sampled during the mission.

Table II. Measured geographic coordinates of the selected soil sampling sites in Datum WGS 1984

Site	Date	Sampling location	Geographic coordinates		Projection coordinates UTM		
			North	East	Zone	Northing	Easting
Zenin Farm	12/03/12	**ZEa**	30°02'31.26"N	31°09'59.42"E	36R	323223.098	3324857.580
	12/03/12	**ZEb**	30°02'33.01"N	31°09'59.76"E	36R	323232.942	3324911.348
	12/03/12	**ZEc**	30°02'29.60"N	31°09'59.37"E	36R	323220.905	3324806.468
Tanash Farm	12/03/12	**TAa**	30°07'44.46"N	31°11'34.26"E	36R	325916.147	3334459.894
	12/03/12	**TAb**	30°07'44.58"N	31°11'35.67"E	36R	325953.848	3334463.135
	12/03/12	**TAc**	30°07'45.47"N	31°11'32.09"E	36R	325858.372	3334491.819
Abu Rawash Farm	12/03/12	**ARa**	30°04'53.15"N	31°04'06.52"E	36R	313843.754	3329381.850
	12/03/12	**ARb**	30°04'06.14"N	31°03'38.55"E	36R	313070.276	3327946.846
El-Salam Farm 1	14/03/12	**ES1a**	30°55'32.35"N	32°29'09.13"E	36R	450879.757	3421475.657
	14/03/12	**ES1b**	30°55'32.67"N	32°29'09.06"E	36R	450877.842	3421485.708
El-Salam Farm 2	14/03/12	**ES2a**	30°56'17.54"N	32°28'57.04"E	36R	450565.215	3422868.499
	14/03/12	**ES2b**	30°56'17.99"N	32°28'56.75"E	36R	450557.528	3422882.330
	14/03/12	**ES2c**	30°56'24.10"N	32°28'54.12"E	36R	450488.621	3423070.800
El-Salam Farm 3	14/03/12	**ES3a**	30°58'29.96"N	32°27'03.58"E	36R	447574.475	3426959.305
	14/03/12	**ES3b**	30°58'29.30"N	32°27'03.73"E	36R	447578.497	3426938.969
Kafr el-Sheikh Farm	15/03/12	**KSa**	31°28'24.91"N	31°11'48.29"E	36R	328694.186	3483496.869
	15/03/12	**KSb**	31°28'23.33"N	31°11'51.45"E	36R	328776.969	3483446.907
	15/03/12	**KSc**	31°28'22.52"N	31°11'52.84"E	36R	328813.207	3483421.263
	15/03/12	**KSd**	31°28'28.89"N	31°11'51.06"E	36R	328769.339	3483618.155
	15/03/12	**KSe**	31°28'30.52"N	31°12'01.12"E	36R	329035.741	3483664.166

6.3. Presentation of the study sites nearby Cairo

Figure 3. Location of the three study sites or farms nearby Cairo (satellite imagery from 10 km above ground level)

6.3.1. Abu Rawash Farm (Konbora) Irrigation with mixed sewage and industrial waste water

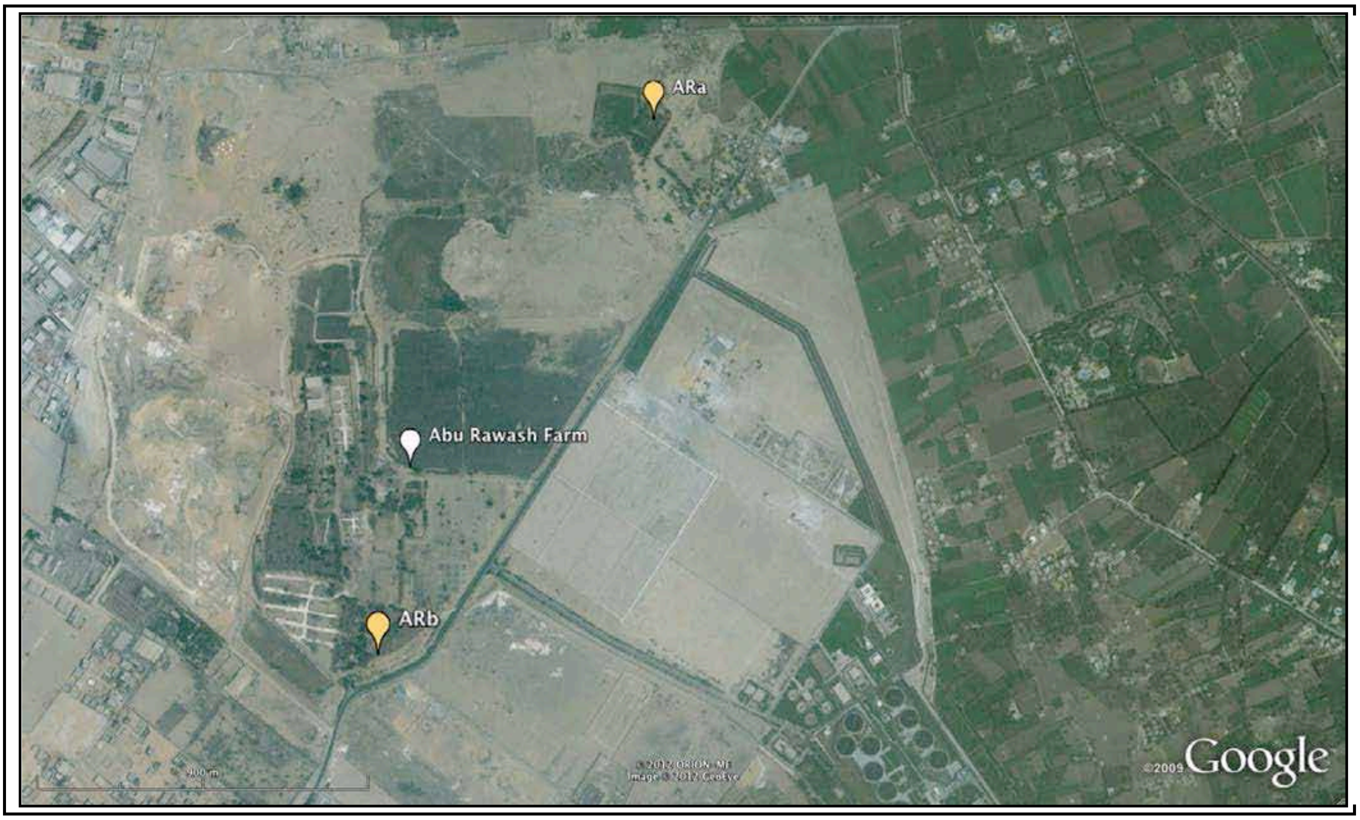


Figure 4. Overview of the Abu Rawash Farm (satellite imagery from 900 m above ground level)

Figure 5. Spoil sampling in the northern part of the Abu Rawash Farm (satellite imagery from 100 m above ground level)

Figure 6. Soil sampling in the southern part of the Abu Rawash Farm (satellite imagery from 100 m above ground level)

6.3.2. Zenin Farm

Irrigation with sewage water (El-Motamadia canal from sewer plant)

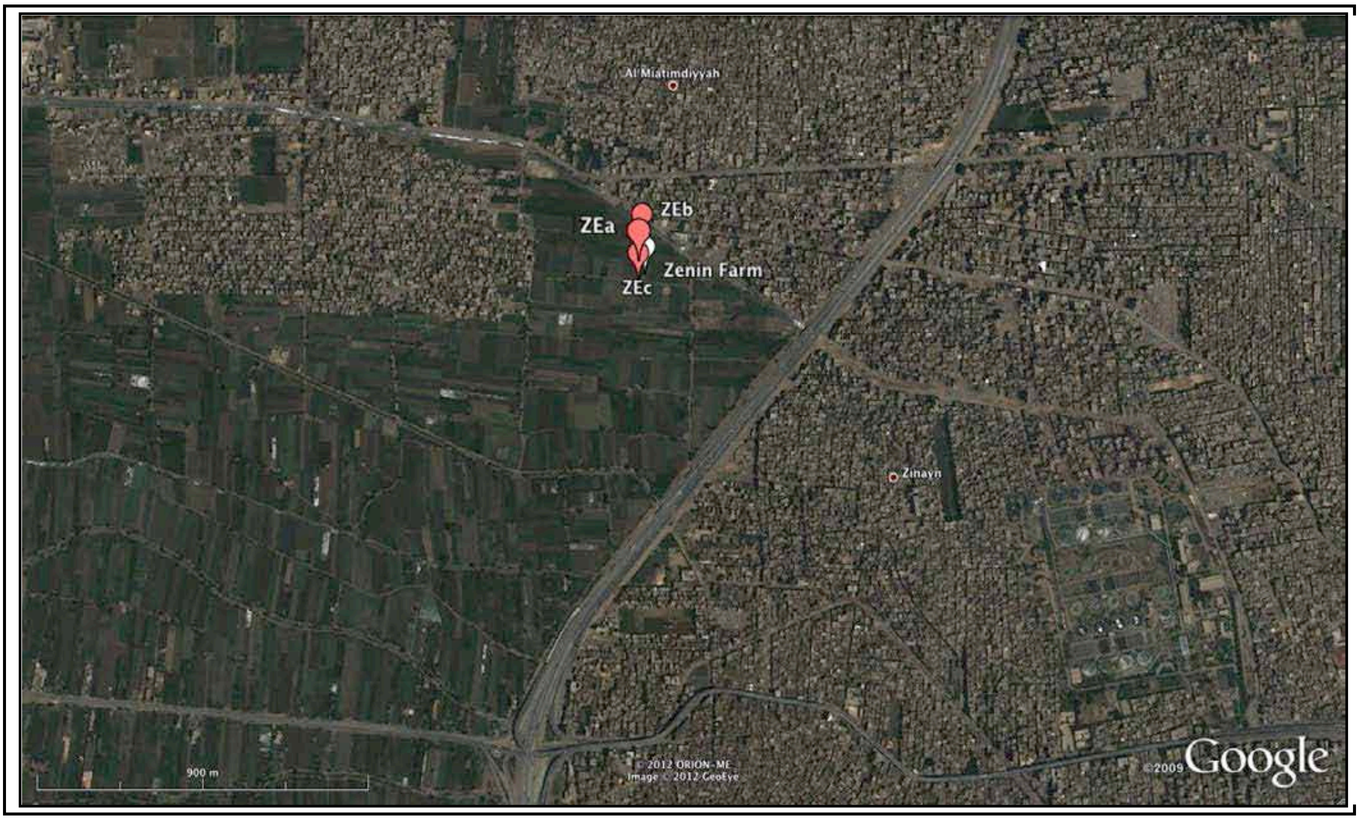


Figure 7. Overview of the Zenin Farm at Motamadia, Cairo (satellite imagery from 900 m above ground level)

Figure 8. Soil sampling from the Zenin Farm (satellite imagery from 100 m above ground level)

6.3.3. Tanash Farm: Irrigation with Nile river water (control site)

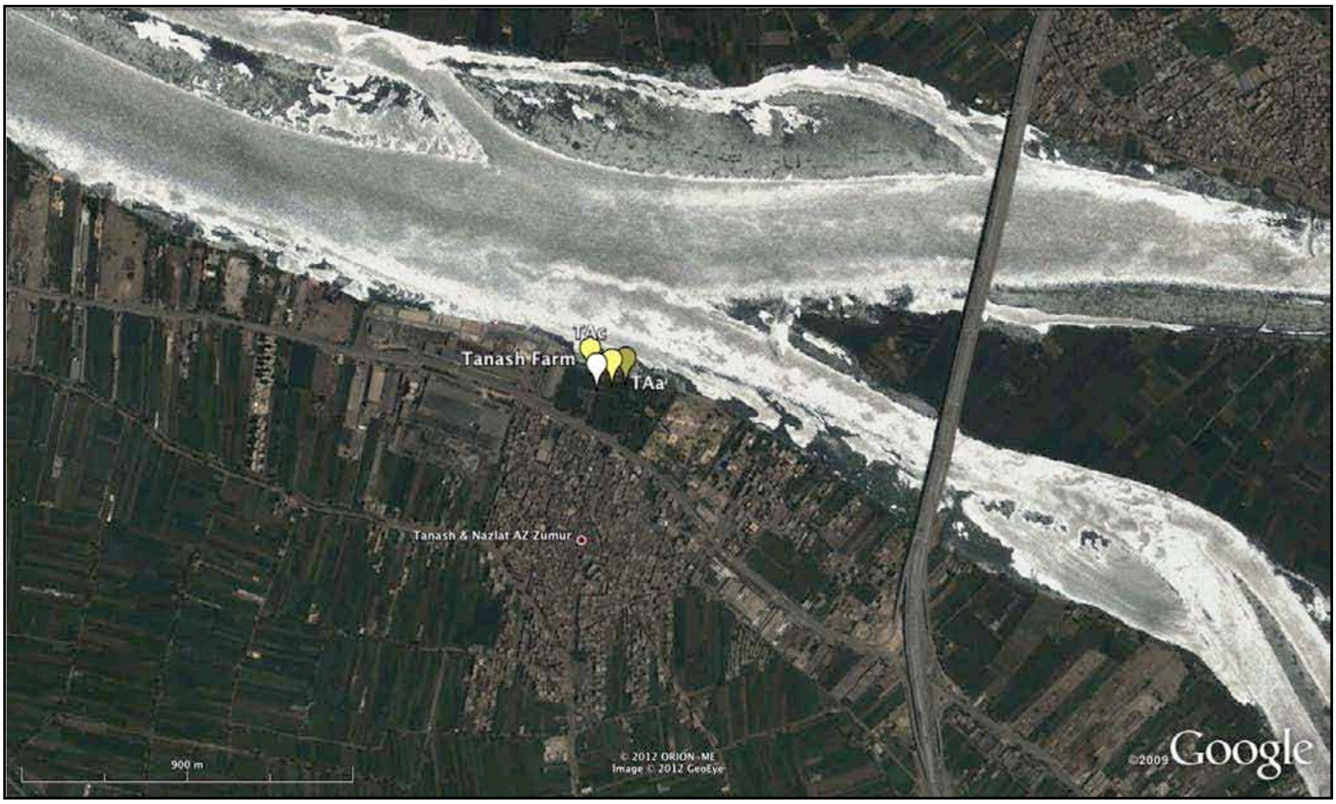


Figure 9. Overview of the Tanash Farm along side Nile river (satellite imagery from 900 m above ground level)

Figure 10. Soil sampling from the Tanash Farm (satellite imagery from 100 m above ground level)

6.4. Presentation of the study site in North Sinai
Irrigation with mixed drainage, sewage and fresh Nile river water

Figure 11. Location of the three farms from El-Salam site in North Sinai (satellite imagery from 10 km above ground level)

Three farms were selected by the Egyptian team in North Sinai area. They are distributed alongside a toposequence starting from the edge of the sandy plateau to the Nile river delta. The soils are more and more clayey and saline downslope.

An overview and a detailed map (in Arabic) are provided in Appendice 11b to show the irrigation and drainage system supplying water from West-East El-Salam canal.

6.4.1. El-Salam Farm 1

Figure 12. Overview of the El-Salam Farm 1 (satellite imagery from 900 m above ground level)

Figure 13. Soil sampling from the El-Salam Farm 1 (satellite imagery from 100 m above ground level)

6.4.2. El-Salam Farm 2

Figure 14. Overview of the El-Salam Farm 2 (satellite imagery from 900 m above ground level)

Figure 15. Soil sampling from the El-Salam Farm 2 (satellite imagery from 100 m above ground level)

6.4.3. El-Salam Farm 3

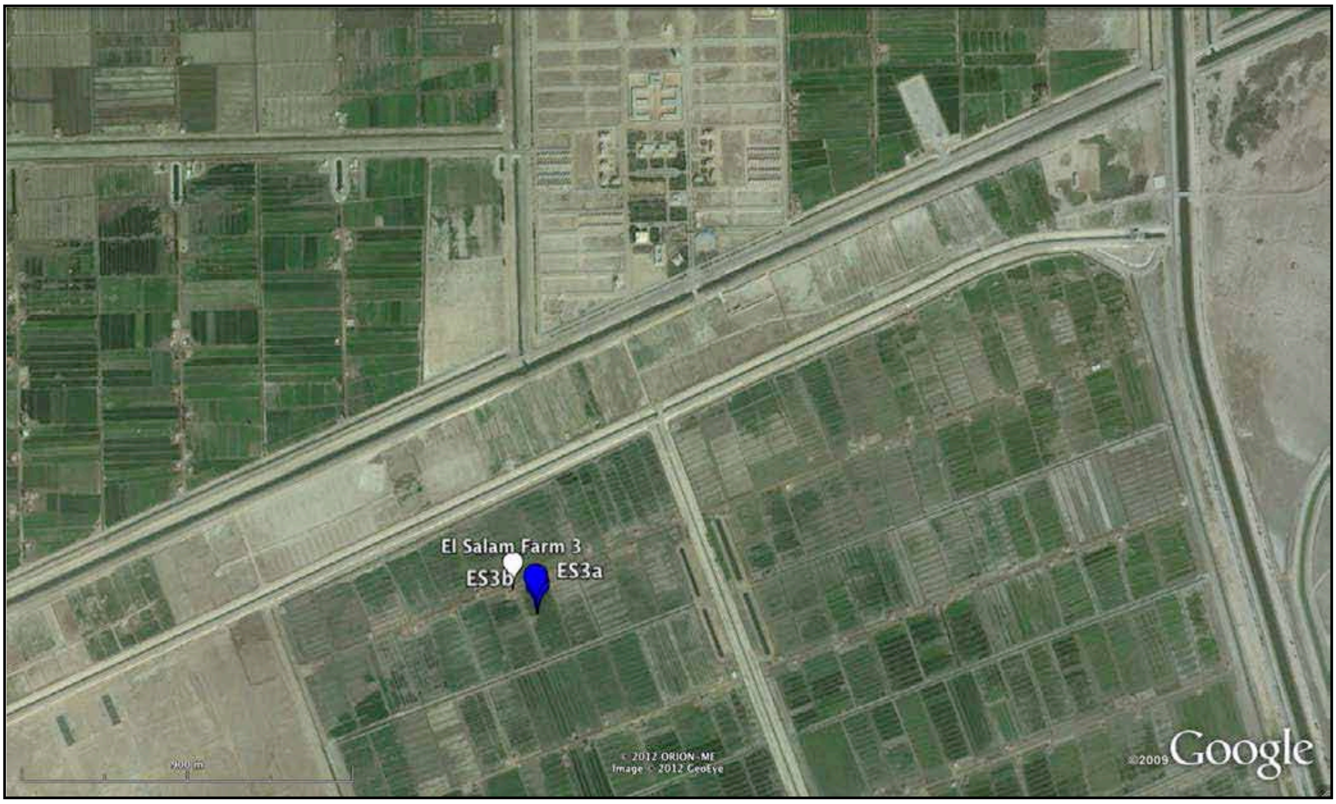


Figure 16. Overview of the El-Salam Farm 3 (satellite imagery from 900 m above ground level)

Figure 17. Soil sampling from the El-Salam Farm 3 (satellite imagery from 100 m above ground level)

6.5. Presentation of the study site in North Nile delta

Irrigation with drainage and industrial waste water

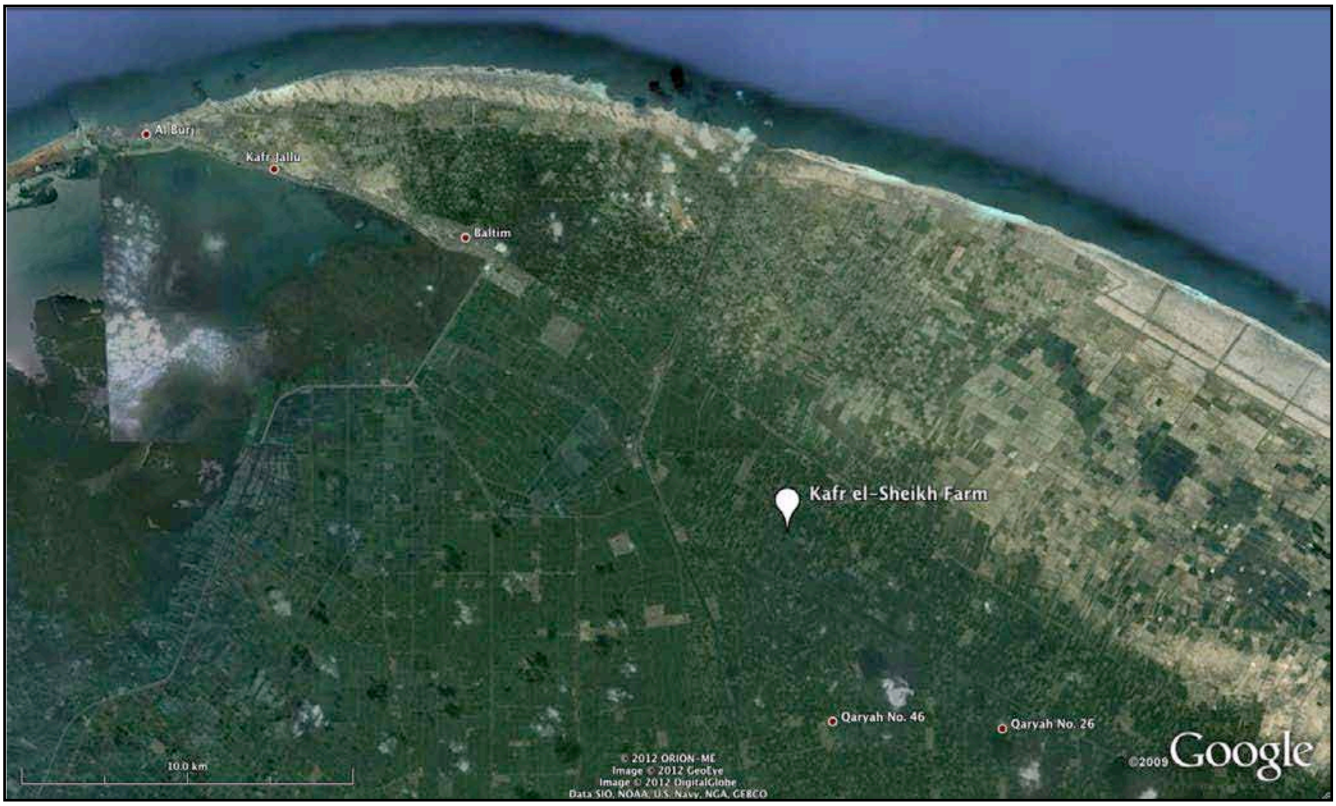


Figure 18. Location of the farm from Kafr el-Sheikh site in North Nile delta (satellite imagery from 10 km above ground level)

Figure 19. Overview of the Kafr el Sheikh Farm (satellite imagery from 900 m above ground level)

Figure 20. Soil sampling from the the Kafr el Sheikh Farm (satellite imagery from 150 m above ground level)

7. Assessement of bioclimatological data

The WP2 workpackage has the objective of improving the accuracy of the bioclimatological data for a given study site. Used as the input data of water transfer models, such as Kamel® model (BRAUDEAU and MOHTAR, 2009), it will lead to calculate water balance and perform simulation of soil water content.

The amount of water required to compensate the evapotranspiration loss from the cropped field is defined as crop water requirement. Although the values for crop evapotranspiration (also called actual evapotranspiration) and crop water requirement are identical, crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration. The irrigation water requirement basically represents the difference between the crop water requirement and effective precipitation. The irrigation water requirement also includes additional water for leaching of salts and to compensate for non-uniformity of water application (ALLEN et al., 1998).

7.1. Evapotranspiration calculation procedure

Detailed calculation procedures presented in ALLEN et al. (1998) leads to derive bioclimatological parameters (bioclimate) from the meteorological data (weather or climate). For a given study site and time period, the main parameters to consider are global radiation (R_g), net radiation (R_n), potential evapotranspiration (E_p) and actual (or crop) evapotranspiration (E_a). Moreover, procedures have been developed for estimating missing climatic parameters.

Are determined step by step:

. R_g from astronomical calculations (relative earth-sun distance), geographical coordinates (altitude in m latitude in decimal degrees and minutes) and the daily sunshine duration;

. R_n from R_g, air temperature, wind speed and air humidity data;

. E_p from R_n, air temperature, wind speed and air humidity data according to the formula of PENMAN (1948);

. E_a from E_p multiplied by a crop coefficient (K_c) which varies according to the phenological state of vegetation or from the formula of MONTEITH (1965).

The two last steps are included within the so-called FAO Penman-Monteith method (ALLEN et al., 1998).

The FAO Penman-Monteith equation determines the potential evapotranspiration (E_p) from the hypothetical grass reference surface and provides a standard to which evapotranspiration in different periods of the year or in other regions can be compared and to which the evapotranspiration from other crops can be related. The only factors affecting E_p are climatic parameters. Consequently, E_p is a climatic parameter and can be computed from weather data. E_p expresses the evaporating power of the atmosphere at a specific location and time of the year and does not consider the crop characteristics and soil factors. The FAO Penman-Monteith method is recommended as the sole method for determining E_p. The method has been selected because it closely approximates grass E_p at the location evaluated, is physically based, and explicitly incorporates both physiological and aerodynamic parameters.

Crop evapotranspiration E_a can be calculated from climatic data and by integrating directly the crop resistance, leaf index, albedo and air resistance factors in the Penman-Monteith approach.

$E_{a(PENMAN\text{-}MONTEITH)} = E_p / (1 + ((\gamma /(\Delta + \gamma)) (r_c\ r_a)))$ (MONTEITH, 1965)

where Δ is the slope of the curve relating saturation vapor pressure to temperature (kPa °C^{-1}); r_c canopy resistance (s m^{-1}); $r_c=r_s/LAI$; with r_s stomatal resistance of the leaf (s m^{-1}); LAI leaf area index; r_a aerodynamic resistance (s m^{-1}).

The effects of characteristics that distinguish field crops from the reference grass crop are integrated into the crop coefficient K_c. Depending on the purpose of the calculation, the required accuracy, the available climatic data and the time step with which the calculations have to be executed, a distinction is made between two calculation methods. Differences in leaf anatomy, stomatal characteristics, aerodynamic properties and even albedo cause the crop evapotranspiration to differ from the reference crop evapotranspiration under the same climatic conditions. Due to variations in the crop characteristics throughout its growing season, K_c for a given crop changes from sowing till harvest.

Meteorological data are acquired from two possible sources of data recordings:
. one or more station(s) nearby the study site and belonging to the national meteorological network;
. a station temporarily installed according to the "*Bowen*" method.

7.2. Measurement of actual evapotranspiration in North Sinai from meteorological data

After the two missions, the El-Salam Farm 1 focused more attention for E_p and E_a calculations according the following criteria:
. homogenity of the vegetation cover (orange grove).
. accessibility by road;
. power and water supplies;
. facilities, such as accommodation, catering and human resources, within a protected and secure area.

The design of the plantation is given in Appendice 11c. The orange-tree plantation has an area of 80 ha and is one of the experimental stations of the Egyptian partner (NRC). The water quality of the irrigation water is stable and dosed by mixed water from sewage, drainage and Nile origins.

As a first approach, E_p and E_a were calculated from a given weather station. The closest meteorological station from El-Salam Farm 1 in North Sinai is Al-Arish located 190 km East (latitude 31.08°N, longitude 33.83°E, elevation 31 m). The climate and the coastal location are nearly similar. Meteorological data were provided by Rafat Ramdan ALI on a daily basis from 2005 to 2010. Missing data are estimated from the mean value of the month except when precipitation is occurring.

The monthly mean values of the meteorological data are calculated for each year and displayed in Appendice 11d. At each time step, R_g, R_n, E_p and E_a parameters are calculated according the above procedure (FAO Penman-Monteith method) and synthesised in Appendice 11d. The crop coefficient (K_c) taken in account for the E_a calculation is 0.8 (BOUAZZAMA and BAHRI, 2009). Table III presents the average value of the monthly mean values over the 2005-2010 period for both types of data.

Table III. Monthly and annually raw meteorological data and calculated bioclimatological data in North Sinai over the 2005-2010 period (Al Arish station)

Time period	T	TM	Tm	SLP	H	PP	VV	V	VM	E_p	Ea	R_g	R_n
		°C		mb	%	mm	km	km h^{-1}		mm d^{-1}		MJ m^{-2} d^{-1}	
January	12.9	19.7	7.0	1018.5	66.9	**21.7**	8.7	9.4	18.3	2.75	**2.20**	21.6	16.7
February	14.3	21.0	8.5	1016.0	65.9	**14.6**	8.5	10.4	20.1	3.03	**2.42**	22.1	17.0
March	16.7	23.9	10.4	1015.3	62.6	**6.3**	8.6	9.4	19.3	3.07	**2.46**	22.2	17.1
April	18.9	26.3	12.3	1013.3	64.4	**3.9**	8.7	9.0	19.4	3.35	**2.68**	21.6	16.7
May	18.6	25.3	12.3	1014.0	65.9	**17.5**	9.1	9.2	18.9	3.42	**2.74**	20.8	16.1
June	25.3	31.8	18.8	1009.8	66.1	**0.0**	9.5	7.5	17.0	3.99	**3.19**	21.5	16.6
July	27.1	33.0	21.4	1007.5	68.8	**0.0**	9.3	7.0	16.4	4.26	**3.41**	20.5	15.8
August	27.6	33.4	22.2	1007.4	70.5	**0.0**	9.3	6.3	14.9	4.20	**3.36**	21.7	16.7
September	26.2	32.0	20.5	1011.3	67.1	**0.0**	9.8	7.0	15.8	4.19	**3.35**	21.7	16.7
October	23.3	29.7	17.5	1014.3	68.0	**16.9**	9.7	6.9	15.3	3.67	**2.94**	22.2	17.1
November	18.4	25.5	12.2	1016.8	67.9	**2.2**	9.6	8.0	15.8	3.16	**2.53**	24.3	18.7
December	14.7	22.2	8.7	1017.7	64.9	**12.4**	8.8	8.5	16.9	2.70	**2.16**	19.2	14.8
Annual mean	20.3	27.0	14.3	1013.5	66.6		9.1	8.2	17.3	3.48	**2.79**	21.6	16.7
Annual amount (mm)						**95.4**				1271.49	**1017.19**		

Raw meteorological data

T	Air temperature (in °C)
TM	Maximum air temperature (in °C)
Tm	Minimum air temperature (in °C)
SLP	Sea level pressure (in mb)
H	Relative humidity (in %)
PP	Precipitation amount (in mm)
VV	Visibility (in km)
V	Wind speed (in km h^{-1})
VM	Maximum sustained wind speed (in km h^{-1})

Calculated data using the FAO Penman-Monteith method

E_p	Potential evapotranspiration (in mm d^{-1})
E_a	Actual evapotranspiration (in mm d^{-1})
I_g	Global radiation (in MJ m^{-2} d^{-1})
I_n	Net radiation (in MJ m^{-2} d^{-1})

Over the 2005-2010 period, the monthly mean values of air temperature (T), relative air humidity (H), precipitation (PP) and potential evapotranspiration (E_p) are presented in Figure 21.

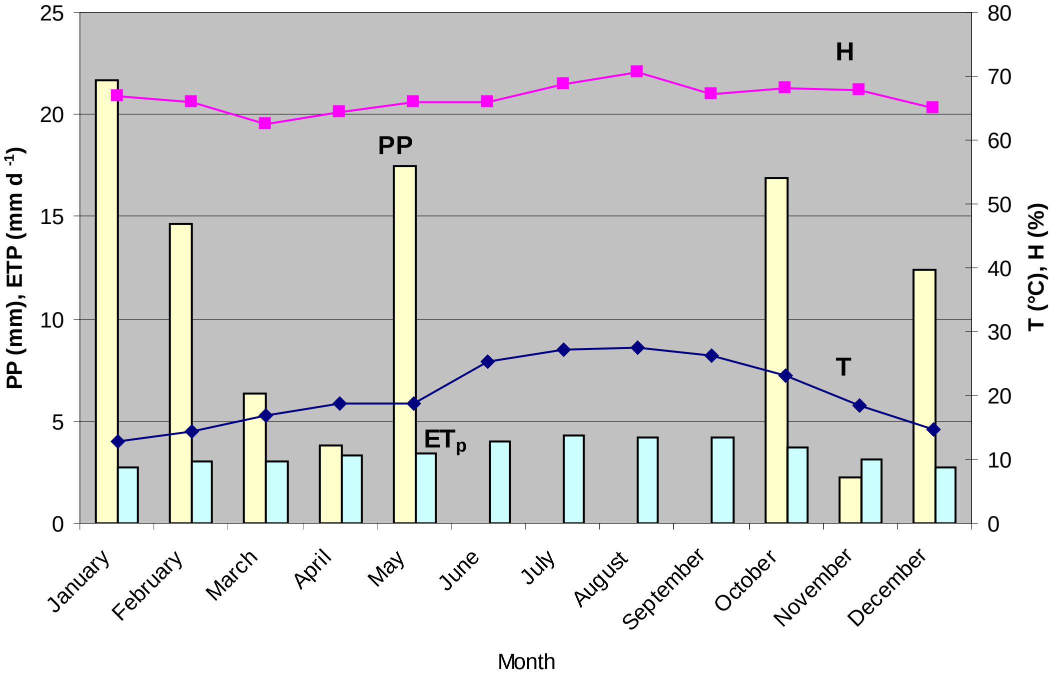


Figure 21. Monthly mean values of air temperature (T), relative air humidity (H), precipitation (PP) and potential evapotranspiration (E_p) in North Sinai (Al Arish station) over the 2005-2010 period

The above results were presented as a poster at the XXIVth Conference of the International Association of Climatology, held in Grenoble from 5 to 8 September 2012 (NIZINSKI et al., 2012). The content of poster presentation is showed in Appendice 11e.

7.3. Measurement of actual evapotranspiration in field using the Bowen Ratio method

Principle

The Energy Balance Bowen Ratio (EBBR) method is widely used to calculate latent heat flux and thus actual evapotranspiration rates (MALIVA and MISSIMER, 2012). The mean actual evapotranspiration of a given vegetation cover is quantify from measurements of the net radiation (R_n), heat stored in the biomass and the soil (G_s), and from the Bowen ratio, assessed magnitude (BOWEN, 1926).

The Bowen ratio (β) accounts for the distribution of the available energy on the surface level and relates sensible (H) to latent (λE) heat flux as follows:

$$\beta = H/\lambda E$$

The Bowen ratio is used with the energy balance at the stand level, here simplified:

$$R_n = H + \lambda E + G_s$$

where R_n is net radiation; H is sensible heat flux; λE is latent heat flux of water vaporization; G_s heat stored in the biomass and the soil. All the variables are expressed in W m^{-2}.

The two above relations lead to calculate latent heat flux or actual evapotranspiration (λE), as the following equation:

$$\lambda E = (R_n - G_s) / (1 + \beta)$$

The values of $\lambda E_{(t)}$ are calculated over a recurrent time period and are cumulated over the day to obtain the daily actual evapotranspiration $E_{a(BOWEN)}$ or λE_d:

$$E_{a(BOWEN)} = \lambda E_d = \Sigma \lambda E_{(t)} \, dt$$

where λE_d is daily actual evapotranspiration (in mm d^{-1}); $\lambda E_{(t)}$ is actual evapotranspiration (in J m^{-2} s^{-1}) for dt = 1,200 s (20 minute period).

The reliability of this method is assessed by comparison with the method of Penman-Monteith equation (MONTEITH, 1965) and the water balance method.

Application of Bowen ratio method in a test-field

The Bowen ratio method, applied to a given canopy, requires the installation of a metal mast 7 m high which provides a vertical support for sensors measuring climatic parameters. It was set up on the lawn of IRD France-Nord in Bondy to test the reliability of the datalogger (CR 1000, Campbell Scientific®) and its sensors.

The geographical coordinates of the measurement site are given in Table IV.

Table IV. Estimated geographic coordinates of the Bondy study site (from Google Earth Imagery)

Unit	Latitude	Longitude
Degrés décimaux	48.91420225251033°	2.4848918494152485°
Degrés sexagésimaux	N 48°54’51.1272’’	E 2°29’5.6106’’

The climatic measurements were performed using the sensors listed in Table V.

Table V. Characteristics of the sensors used by the Bowen ratio method

Sensor	Company	Type	Parameter	Quantity	Height (m)
Pyranometer	Li-200SZ	Li-cor®	Global radiation	1	6
Net radiometer	REBS/Q-7	Campbell Scientific®	Net radiation	1	6
Anemometer	A100R	Vector Instruments®	Wind speed	2	2 and 5
Temperature/ RH probe	CS215	Campbell Scientific®	Air temperature/ Relative humidity	2	2 and 5

The experimental design was completed by four sensors to measure soil temperature (107 soil temperature probe from Campbell Scientific®) at 15, 25, 35 and 45 cm in depth.

The measurements were carried out from 16 July to 6 November 2012, at three recording frequencies, every minute, every 20 minutes and every day. Table V shows the measurement periods and the number of records for each frequency.

Table V. Characteristics of the data recordings

Time frequency	Time start	Time end	Data recording
mn	16/07 10h56	13/08 10h27	483,497
20 mn	16/07 11h00	13/08 10h20	2,015
day	17/07 00h00	13/08 00h00	28
mn	13/08 10h27	13/10 02h48	1,048,572
20 mn	13/08 10h40	06/11 13h00	6,128

The data files will be treated to calculate ET_a and check the reliability of measurements.

Norbert SILVERA, electronics engineer at IRD (JRU "*Bioemco*"), has contributed to the preparation of the field experiment in:
. ordering and receiving the purchased equipment according to specifications described by Georges NIZINSKI;
. testing the Campbell Scientific® datalogger after wiring the probes;
. digitally configuring the microprocessor of the datalogger as specified by Georges NIZINSKI;
. programming the datalogger for a scan every 20 minutes, depending on the needs of the Bowen ratio method;
. programming the datalogger for a scan every minute and every day, according to the needs of Kamel® model, and verifying the reliability of measures, including R_g et R_n.

Once the tower and its sensors installed, Norbert SILVERA has performed several demonstrations to change the Compact Flash memory card (2GB capacity), initialize the Campbell Scientific® datalogger, download the data using the "*Loggernet*" software from Campbell Scientific® and transfer data in a Microsoft® Excel 2007 spreadsheet (version allowing a maximum storage capacity).

Application of Bowen ratio method in an Egyptian field

The Bowen ratio method will be applied in Egypt under the IRD/AIRD-STDF project. First, the ideal site is El-Salam Farm 1 in North Sinai because of the vegetation cover, namely orange grove, is uniform and homogeneous from a bioclimatic point of view.

The orange grove belongs to Mr. Mohamed Yaya FOUTA who is quite favorable to accommodate experimentation. The site is protected by an enclosure limiting the grove and staff is constantly working. Travel will be in the day and, each time, in the company of scientists and technicians of the National Research Center (Dokki, Cairo). However, accessibility is not guaranteed for security reasons imposed by the French Administration.

8. Assessement of hydrostructural data

The WP4 workpackage has the objective of determining the hydrostructural soil properties for each studied sites.

Principle

BRAUDEAU and MOHTAR (2009) describes the hydrostructural apprach. Morphological observations of soils are moisture related to water functioning taking into account the Representative Elementary Volume Structural (SREV) that:

- contains a fixed mass of solid material as a reference to all the specific variables;
- defines the structural organization, so-called "*Pedostructure*", and water functioning using four curves (shrinkage, potential, swelling and hydraulic conductivity curves).

The pedostructure is the SREV of a soil horizon. It is formed by an assembly of primary peds with mineral grains and two functional porosities well distinguished on the continuous-measured shrinkage curve (Figure 22). The two poral systems define the macroporosity as inter-primary peds and the microporosity as intra-primary peds (Figure 23).

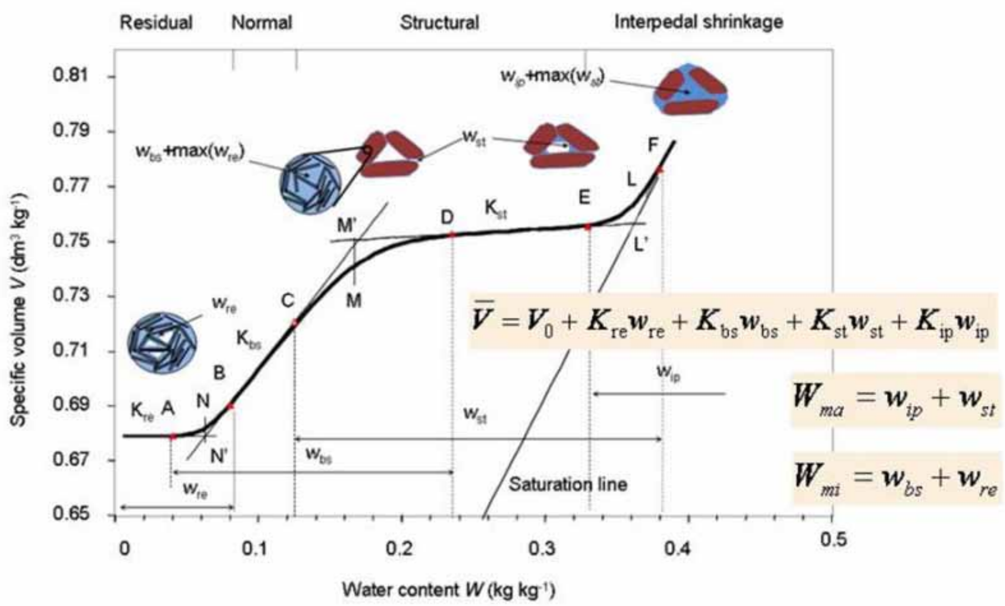


Figure 22. Modelling of a shrinkage curve (after BRAUDEAU and MOHTAR ,2009)

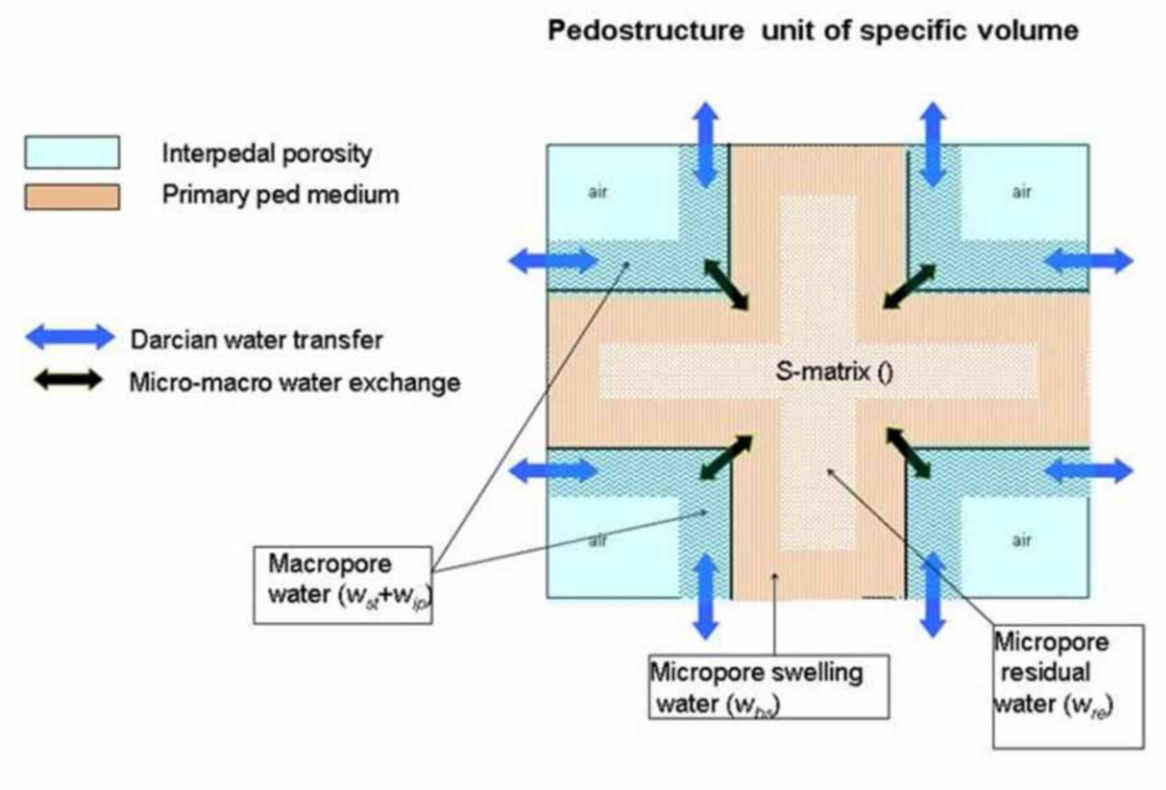


Figure 23. Water functioning within the soil pedostructure (after BRAUDEAU and MOHTAR ,2009)

Measurement device

Soil samples collected in the field using metal cylinders will be analyzed by an automatic newly purchased equipment, so-called "*Typosol*" .The device was manufactured by two companies, "*AGREC*" for the mechanics part and "*SYGA Electronique*" for the electronics part, both located in the Paris region.

It was transported by "*Unione Trans Express*" company and installed November 14, 2012 in the laboratory of the France-Nord IRD centre within the JRU "*Bioemco*" A second device for Erik BRAUDEAU, retired researcher in the QEERI (Qatar Environment and Energy Research Institute), was built simultaneously. It is planned in the next future to provide such equipment by a company specialized in soil instrumentation. French "*Sol Mesures*" company has been contacted and commercial discussions are ongoing with IRD, owner of patents (see below).

In addition, the company "*Valorhiz*", located in Montpellier, already has a prototype of the "*Typosol*" delivered in late 2011. At present, it therefore has some expertise in the implementation of the device as well as in the use. The company can train anyone who wants to get involved in the methodology.

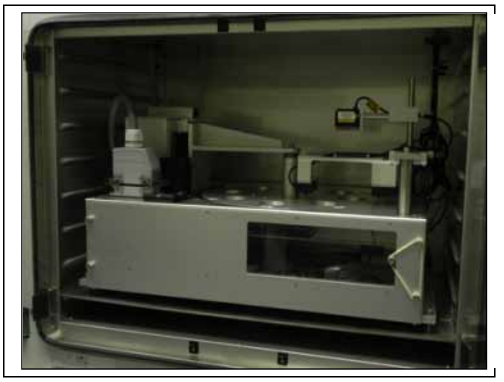
"*Valorhiz*" company is also committed in developing the Kamel model by temporarily recruiting Jérémie FRANÇOIS for the conceptual part and MARCESINI for the technical part. Development is in progress and will be completed in 2013.

A five-day training was requested November 24, 2012 to IRD in order to form eight scientists and technicians from the France-Nord IRD centre and two research partners of Tunisia (Mohamed HACHICHA) and Egypt (Alaa ZAGHLOUL). The requested budget is 7,300 euros with 6,500 euros dedicated for teaching and 800 euros for the accommodation of participants. The training will be performed by Estelle HEDRI from "*Valorhiz*". The official decision is expected in early 2013.

The following photographs show different aspects of the "*Typosol*".

Closed "*Typosol*" in laboratory

Open "*Typosol*" in laboratory



Detail of the "*Typosol*" device within the controlled heating

Two patents were filed July 5, 2011 from the National Institute for Industrial Property (NIIP)
- a so called "*Rétractomètre*" patent under "*Device coupled-measuring hydric parameters*" operated under the brand "*Typosol*" (#1156036 application in classes 9 and 42);
- a so called "*Kamel*" patent under "*Method for determining the hydrostructural parameters of a soil*" (#1156040 application).

They were approved in early 2013.

Figure 24 shows schematically the structure of the Kamel model.

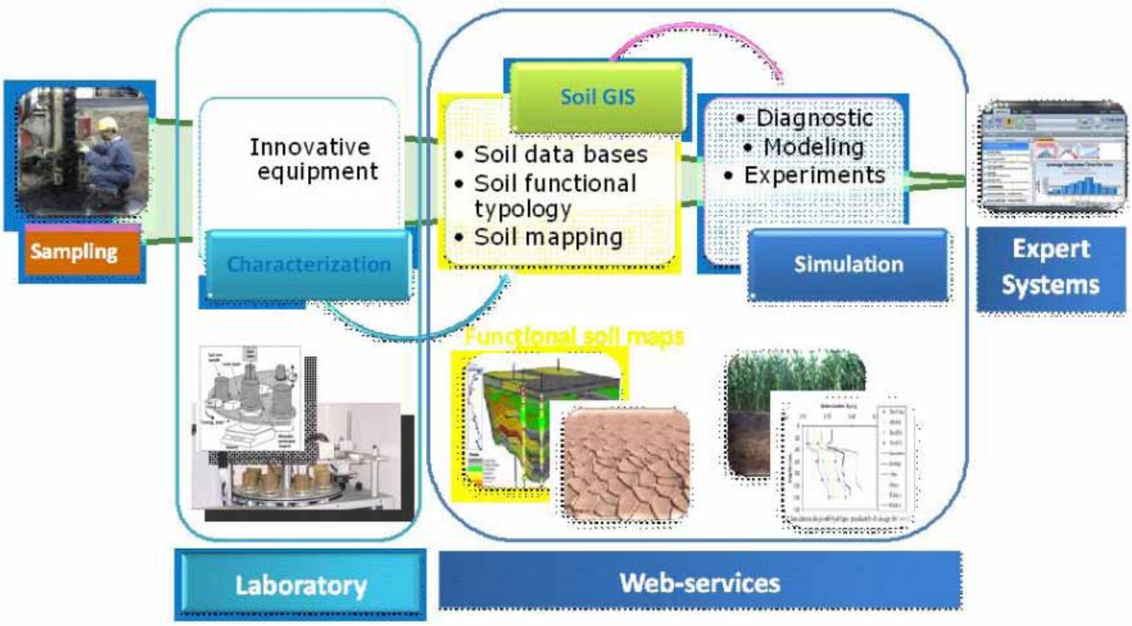


Figure 24. Kamel model structure (after BRAUDEAU and MOHTAR ,2009)

9. Budget

The funding provided in 2011 by IRD/AIRD has been officially confirmed and administratively implemented February 22, 2012. A meeting was held at the IRD/AIRD headquarters in Marseille on May 2nd, 2012 by René Bally, Director of Programming and Training. It was decided to finance up to 40,000 euros the purchasing of the laboratory equipment necessary to characterize the hydrostructural properties of soils, namely a "*Typosol*". The funding was implemented July 20, 2012 and the equipment was delivered to the France-Nord IRD centre November 15, 2012.

In 2012, financial expenses are summarized in Table V.

Table V. Expenses in 2012 within IRD/AIRD-STDF project

Date	Beneficiary	Purpose	Amount EUR
23/02	"*Campbell Scientific*" Company	CR1000 datalogger and accessories	2,345.00
24/02	"*Voyages du Midi*" Company	Paris-Cairo travel (*J.P. Montoroi*)	823.71
24/02	"*Voyages du Midi*" Company	Paris-Cairo travel (*G. Nizinski*)	823.71
01/03	"*Sportshop*" Company	3 eTrex 20 Garmin GPS	499.16
13/04	"*Campbell Scientific*" Company	CS215 temperature and humidity sensors	613.00
16/05	"*Radiospares*" Company	Electronic components	307.89
28/05	*G. Nizinski*	Mission to Egypt (03-18 March)	2,343.25
07/06	*J.P. Montoroi*	Reimbursement of expenses	71.28
08/06	*J.P. Montoroi*	Mission to Egypt (03-18 March)	2,279.02
13/06	"*Campbell Scientific*" Company	7 m UT920 aluminum tower and accessories	2,222.00
09/11	"*Valorhiz*" Company	"*Typosol*" device	40,000.00
13/11	"*Unione Trans Express*" Company	"*Typosol*" transportation	111.00
		Total (EUR)	52,439.02

The remainder balance, namely 7,560.98 euros will be carried forward in 2013 and available in late March. In 2013, the last year of the project, no additional funding is announced.

10. Bibliography

ALI, R.R., 2003. Evaluation of land degradation of some areas in Middle and North Nile delta, Egypt. PhD thesis, Faculty of Agriculture, Cairo University.

ALI R.R. and ABDEL KAWY W.A.M., 2007. Remote sensing and GIS to assess the soil sustainbility for crops in North Sinai, Egypt**.** *Egypt. J. Remote Sensing & Space Sci.*, 10: 87-106.

ALLEN R.G., PEREIRA L., RAES D., SMITH M., 1998. Crop evapotranspiration - Guidelines for computing crop water requirements. FAO Irrigation and Drainage Papers, Rome, Italy, 56.

BOUAZZAMA B. and BAHRI A., 2009. Détermination des coefficients culturaux de la variété d'oranger « Maroc late » au périmètre irrigué Tadla. Symposium international « *Agriculture durable en région méditerranéenne (AGDUMED)* », 14-16 mai 2009,Rabat, Maroc.

BOWEN I.S., 1926. The ratio of heat losses by conduction and by evaporation from any water surface. *Physical Review*, 27: 779-787.

BRAUDEAU E. and MOHTAR R.H., 2009.Modeling the soil system: bridging the gap between pedology and soil-water physics. *Global and Planetary Change*, 67: 51-61.

BRAUDEAU E., ZAGHLOUL A, 2010. Sustainable Management of Adverse Impacts on Farming and Soil

Ecosystem Associated with Long Term Use of Low Quality Irrigation Water. Joint Innovative Projects Fund, STDF-AIRD, Joint Research Project, Scientific Document, 48 p.

EVETT S., 2008. Gravimetric and volumetric direct measurements of soil water content. In Evett S. (Coord.): "*Field estimation of soil water content. A practical guide to methods, instrumentation and sensor technology*", IAEA, Vienna, Training course series 30, 23-37.

HACHICHA M., BRAUDEAU E., MONTOROI J.-P., 2011. Action thématique structurante. Actes du séminaire de formation en pédologie hydrostructurale : méthodologies de caractérisation et modélisation hydrostructurale du sol pour la gestion des eaux et des sols en agriculture irriguée et/ou de précision. INRGREF-DG/ACTA-QEERI-IRD, 96 p.

LOINTIER M., 2011. Sustainable Management of Adverse Impacts on Farming and Soil Ecosystem Associated with Long Term Use of Low Quality Irrigation Water. Mission in Egypt Sept 26th-Oct 1st 2011. AIRD/STDF Report, 5 p.

MALIVA R., MISSIMER, 2012. Arid lands water evaluation and management. Environmental Science, Springer-Verlag, Berlin, 1076 p.

MONTEITH J.L., 1965. Evaporation and environment. The state and movement of water in living organisms. Symposia of the Soc. Exp. Biol., New York, Academic Press, 19: 205-234.

NIZINSKI G., MONTOROI J.-P., LOINTIER M., BRAUDEAU E., 2012. Etude des variations de la conductance stomatique maximale avec l'âge des feuilles chez l'oranger (orangeraie d'El-Salam, Nord Sinaï, Egypte). Projet de stage en Master 2ème année, IRD-UPEC, Bondy-Créteil, France, 8 p.

NIZINSKI J.J., MONTOROI J.-P., LOINTIER M., SILVERA N., ZAGHLOUL A., ALI R., SABER M., BRAUDEAU E., 2012. Modélisation des flux énergétiques et hydriques d'un système « *Sol-Orangeraie* » (Nord Sinaï, Egypte). Poster displayed in 24ème colloque de l'Association Internationale de Climatologie « *Climat régionaux : observation et modélisation* », 5-8 sept. 2012, Grenoble, France.

PENMAN H.L., 1948. Natural evaporation from open water balance bare soil, and grass. *Proceedings of the Royal Society of London*, Series A, 193: 120-145.

ZAGHLOUL A., 2011. Sustainable Management of Adverse Impacts on Farming and Soil Ecosystem Associated with Long Term Use of Low Quality Irrigation Water. First Progress Report, AIRD-STDF, Project ID 3033, 19 p.

ZAGHLOUL A., 2012. Sustainable Management of Adverse Impacts on Farming and Soil Ecosystem Associated with Long Term Use of Low Quality Irrigation Water. Second Progress Report, AIRD-STDF, Project ID 3033, 191 p.

ZAGHLOUL A., LOINTIER M., SABER M., ALI R., 2011. Sustainable Management of Adverse Impacts on Farming and Soil Ecosystem Associated with Long Term Use of Low Quality Irrigation Water. Bibliographic Data Base, AIRD-STDF, Project ID 3033, 375 p.

11. Appendices

11a. Mission schedule

● Mission from November 2011

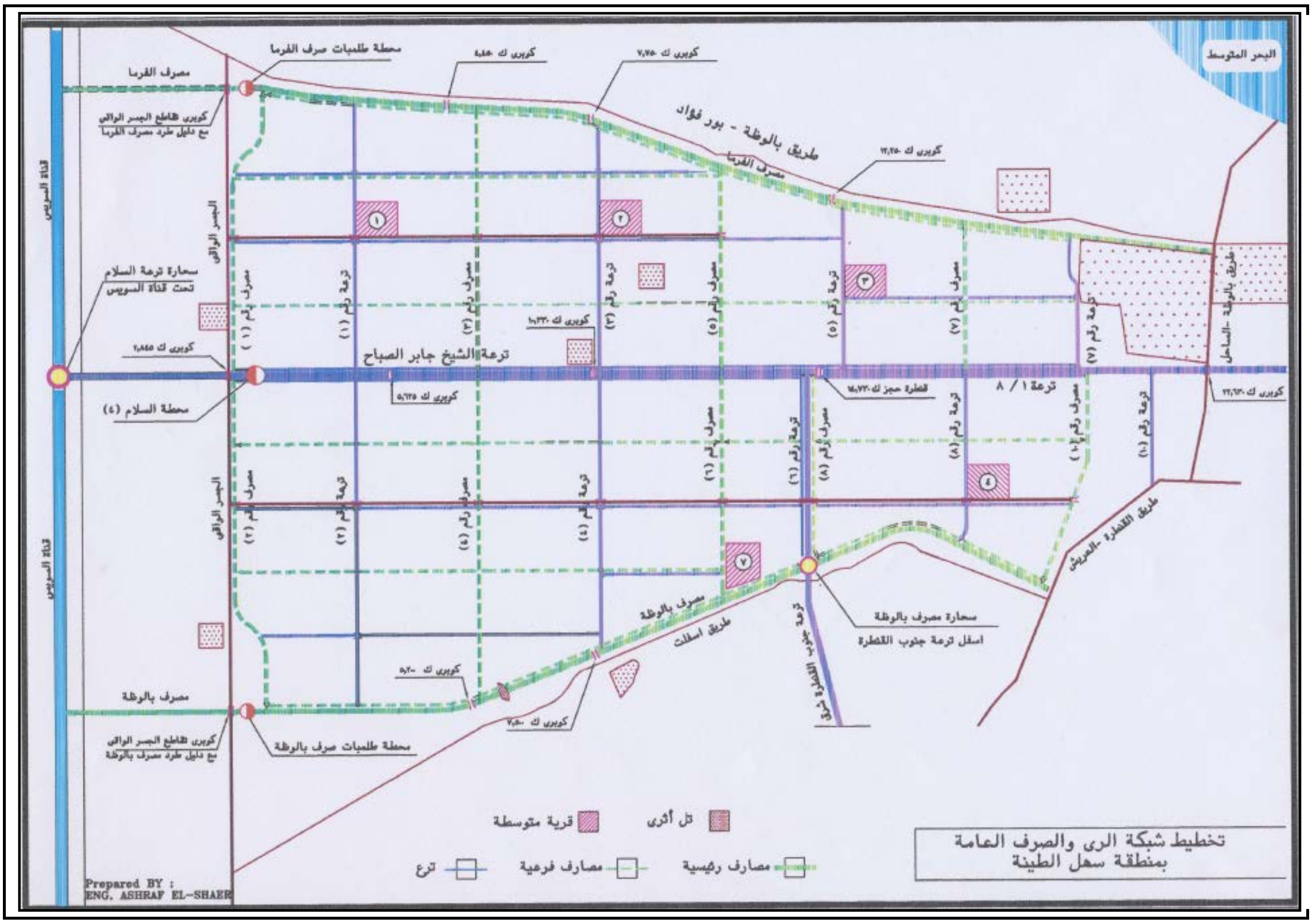
Thursday 10th	Arrival.
Friday 11th	Excursion in Cairo.
Saturday 12th	Meeting with Prof. Dr. Alaa ZAGHLOUL (*alaazaghloul2002@yahoo.com*): first contact and discussion on the ongoing AIRD-STDF project.
Sunday 13th	Meeting at IRD (Maadi, Cairo) with Said JABBOURI (*said.jabbouri@ird.fr*), Head of IRD in Egypt and Amro Fayez BAHGAT(*amro.fayez@ird.fr*), administrative assistant: discussion on the ongoing AIRD-STDF project.
Monday 14th	Meeting at National Research Center (NRC, Dokki, Cairo) with Alaa ZAGHLOUL, Prof. Mohamed SABER (*msaber1941@yahoo.com*) and Dr. Rafat Ramadan ALI (*bediertop@yahoo.com*): laboratory visit and discussion on the ongoing AIRD-STDF project.
Tuesday 15th	Work meeting.
Wednesday 16th	Work meeting.
Thursday 17th	Field trip to Abu-Rawash Sewage Farm with Alaa ZAGHLOUL and two colleagues from NRC. Meeting with François MOLLE (*francois.molle@ird.fr*) from IRD posting at International Center for Agricultural Research in the Dry Areas (ICARDA, Dokki, Cairo) and working on a project related to the global water system within the delta of Nile river.
Friday 18th	Excursion in Cairo and its surroundings.
Saturday 19th	Departure.

● Mission from March 2011

Saturday 3rd	Arrival from Paris, France.
Sunday 4th	Excursion in Cairo and phone discussion with Prof. Dr. Alaa ZAGHLOUL.
Monday 5th	Meeting at National Research Center (NRC, Dokki, Cairo) with Alaa ZAGHLOUL, Prof. Mohamed SABER and Dr. Rafat Ramadan ALI: discussion on the ongoing AIRD-STDF project.
Tuesday 6th	Meeting at NRC with Rafat Ramadan ALI: discussion on the ongoing AIRD-STDF project.
Wednesday 7th	Meeting at IRD (Maadi, cairo) with Said JABBOURI, Head of IRD in Egypt and Amro Fayez BAHGAT, administrative assistant: discussion on the ongoing AIRD-STDF project. Excursion in Cairo.
Thursday 8th	Work meeting.
Friday 9th	Work meeting.
Saturday 10th	Excursion in Cairo.
Sunday 11th	Meeting at NRC with Alaa ZAGHLOUL: discussion on future field trips. Introduction to Dr. Mohamed ABDELHADY (*hadymnrc@yahoo.com*), specialist in "*Water and Soil Management*". Work meeting.
Monday 12th	Field trip to three sites surrounding Cairo (Abu-Rawash, Tanash and Zenin farms) with Alaa ZAGHLOUL and two colleagues from NRC (Mohamed Fawzi EL-SAYED, Agricultural Technician, and Sobhi ABO-EL-HAGAG, Agricultural Specialist).

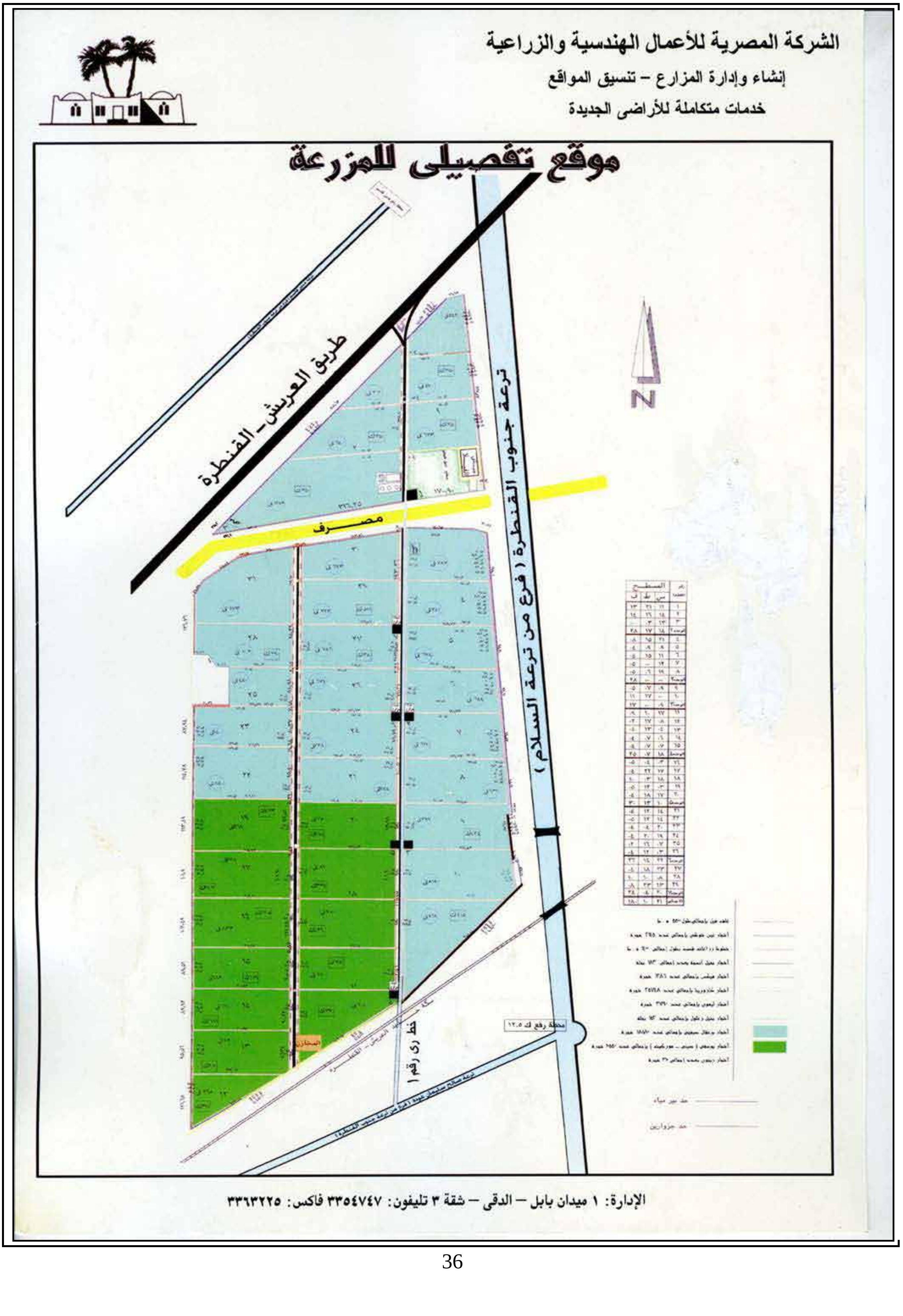
Tuesday 13th	Meeting at NRC with Rafat Ramadan ALI and Prof. Mohmoud Zaki Salem AWAD: discussion on future field trips. With Rafat Ramadan ALI, visit of "*Soils, Water and Environment Research Institute*" (SWERI) from Agricultural Research Center (ARC, Giza, Cairo), Ministry of Agriculture and Land Reclamation: discussion with Dr. Eng. Mohamed ISMAIL (*ismailm@sweri.com*) and Dr. Rafaat Kamal YACOUB (*rkamal@mail.com*) from Soil Survey and Classification Research Department, Remote Sensing and GIS Unit. Meeting with Prof. Dr. Ayman F. ABOU HADID, President of ARC (*ruafah@rusys.eg.net*). Work meeting.
Wednesday 14th	Field trip to North Sinai (El-Salam Farm) with Alaa ZAGHLOUL and Sobhi ABO-EL-HAGAG from NRC. Meeting with Mohamed YAYA FOUTA, Head of a fruit-tree plantation (oranges and mandarins) and walking within the plantation. Visit of two other farms nearby the El-Salam canal.
Thursday 15th	Field trip to Nile delta site (nearby Balsim and Kafr el-Sheikh) with Dr. Rafat ALI and Sobhi ABO-EL-HAGAG from NRC. Meeting with Mettwally Abbass HAMADA, Farm owner and Assistant Professor of Agronomy at Ain Shams University, and his nephew Mohamed EIDA (*medanrc@yahoo;com*) from NRC (Agriculture and Microbiology Department).
Friday 16th	Excursion in Cairo. Meeting with Alaa ZAGHLOUL and Prof. Dr. Malak Abd El Halim RAMADAN (NRC): first contact and discussion on the ongoing AIRD-STDF project.
Saturday 17th	Excursion in Cairo.
Sunday 18th	Departure to Paris, France

11b. Map of irrigation network in North Sinai area



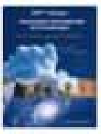
البحر المتوسط
مصرف القرما
محطة طلمبات صرف القرما
طريق بالوظة - بور فؤاد
قناة السويس
الجسر الواقى
سحارة ترعة السلام
تحت قناة السويس
ترعة الشيخ جابر الصباح
محطة السلام (٤)
ترعة ١ / ٨
مصرف بالوظة
طريق اسفلت
سحارة مصرف بالوظة
اسفل ترعة جنوب القنطرة
ترعة جنوب القنطرة شرق
محطة طلمبات صرف بالوظة
طريق القنطرة -العريش
طريق بالوظة -الساحل
قرية متوسطة
تل أثرى
ترع
مصارف فرعية
مصارف رئيسية
تخطيط شبكة الرى والصرف العامة
بمنطقة سهل الطينة
Prepared BY :
ENG. ASHRAF EL-SHAER

11c. Map of El-Salam Farm



11d. Bioclimatological data (El Arish, Egypt, 2005-2010)

Time period		T	TM	Tm	SLP	H	PP	VV	V	VM	E_p	E_a	R_g	R_n
			°C		mb	%	mm	km	km h^{-1}		mm d^{-1}		MJ m^{-2} d^{-1}	
January	2005	13.4	20.1	7.6	1017.2	68.6	12.7	8.3	11.8	22.4	3.29	2.64	21.5	16.6
	2006	12.4	18.7	7.2	1017.9	70.1	36.3	7.4	9.3	18.7	2.60	2.08	21.5	16.6
	2007	12.4	18.5	7.0	1021.4	73.3	29.7	8.7	9.1	18.0	2.75	2.20	21.6	16.7
	2008	11.0	17.6	5.1	1018.8	64.7	29.5	9.6	9.7	17.8	2.64	2.11	21.6	16.7
	2009	13.3	20.8	6.8	1018.8	60.7	8.1	9.2	6.2	14.3	2.14	1.71	21.7	16.7
	2010	14.9	22.8	8.4	1016.8	64.1	14.0	9.3	10.4	18.4	3.07	2.46	21.7	16.7
February	2005	13.9	20.3	7.9	1016.3	62.4	3.6	8.6	13.0	23.8	3.32	2.65	22.0	16.9
	2006	14.2	20.0	9.0	1015.4	69.1	26.4	5.9	10.7	22.2	2.98	2.38	21.8	16.8
	2007	14.2	20.8	8.7	1014.9	69.1	6.1	8.7	10.2	20.6	3.09	2.47	21.9	16.9
	2008	12.6	19.3	6.7	1020.6	72.5	13.7	9.4	7.9	15.8	2.57	2.06	22.3	17.2
	2009	14.6	22.2	7.9	1015.1	58.5	11.2	9.3	8.9	18.2	2.68	2.15	22.2	17.1
	2010	16.3	23.7	10.5	1014.0	63.5	26.7	9.4	11.4	20.0	3.53	2.83	22.1	17.0
March	2005	16.0	22.8	9.7	1016.7	67.7	13.0	7.9	8.4	19.1	2.89	2.31	21.9	16.9
	2006	16.1	23.7	9.6	1015.4	61.1	0.0	7.7	9.9	20.8	2.96	2.37	22.0	17.0
	2007	15.8	22.5	9.6	1015.0	66.2	10.9	8.6	8.8	19.2	2.94	2.35	22.1	17.0
	2008	18.4	26.5	11.5	1013.4	60.6	0.0	8.6	7.3	16.6	2.81	2.24	22.3	17.2
	2009	15.6	22.8	8.8	1015.4	57.0	8.1	9.8	10.9	19.7	3.14	2.51	22.3	17.2
	2010	18.6	25.1	12.9	1015.8	62.8	5.8	8.9	10.8	20.1	3.68	2.95	22.3	17.1
April	2005	18.4	25.9	12.0	1014.4	63.2	0.3	8.4	9.7	21.7	3.38	2.71	21.6	16.6
	2006	19.0	26.0	13.3	1011.9	65.7	13.0	7.5	10.6	22.1	3.73	2.98	21.5	16.6
	2007	18.3	25.0	12.0	1012.8	66.3	7.6	8.8	8.7	20.5	3.22	2.58	21.5	16.6
	2008	19.5	27.9	12.1	1013.7	63.0	2.3	8.8	6.4	15.5	2.83	2.26	21.6	16.6
	2009	18.5	26.0	11.6	1013.2	65.7	0.0	9.2	10.0	19.7	3.57	2.85	21.7	16.7
	2010	19.5	26.9	12.9	1013.7	62.5	0.0	9.8	8.7	17.0	3.39	2.71	22.0	17.0
May	2005	13.4	20.1	7.6	1017.2	68.6	12.7	8.3	11.8	22.4	3.27	2.62	20.8	16.0
	2006	21.0	27.2	14.6	1013.1	68.4	0.0	8.9	6.7	17.3	3.15	2.52	20.8	16.0
	2007	22.7	29.5	16.0	1010.2	64.5	62.2	8.4	7.9	18.7	3.58	2.87	20.9	16.1
	2008	11.0	17.6	5.1	1018.8	64.7	29.5	9.6	9.7	17.8	2.62	2.10	20.8	16.0
	2009	21.4	28.2	14.7	1012.9	65.9	0.0	9.6	9.8	18.7	4.01	3.21	20.9	16.1
	2010	22.3	29.2	15.7	1011.7	63.5	0.5	9.6	9.1	18.6	3.90	3.12	20.9	16.1
June	2005	24.5	30.3	18.4	1010.6	68.0	0.0	9.5	7.8	19.0	4.01	3.21	21.6	16.7
	2006	24.8	30.6	18.4	1011.4	67.1	0.0	9.4	6.0	14.9	3.45	2.76	21.6	16.6
	2007	25.1	31.9	18.5	1008.4	65.8	0.0	8.7	5.9	15.1	3.39	2.71	21.6	16.6
	2008	25.8	33.0	19.0	1009.3	64.7	0.0	9.7	7.4	16.5	4.02	3.22	21.5	16.6
	2009	25.6	32.4	18.7	1009.8	66.9	0.0	9.8	9.2	18.3	4.67	3.73	21.5	16.6
	2010	25.9	32.3	20.0	1009.1	63.9	0.0	9.9	8.7	18.4	4.43	3.54	21.5	16.5
July	2005	26.9	33.4	20.9	1008.4	68.8	0.0	8.5	6.3	17.5	3.86	3.09	20.6	15.8
	2006	26.5	32.1	20.9	1008.2	67.8	0.0	9.4	6.4	17.6	3.91	3.12	20.6	15.8
	2007	27.2	33.6	21.3	1006.6	68.9	0.0	8.4	5.0	12.6	3.47	2.77	20.6	15.8
	2008	27.1	33.1	21.2	1006.8	69.0	0.0	9.8	7.2	15.7	4.38	3.50	20.5	15.8
	2009	27.7	33.8	21.7	1007.2	66.9	0.0	9.8	9.4	17.7	5.24	4.19	20.5	15.8
	2010	27.1	32.1	22.2	1007.5	71.3	0.0	10.1	7.9	17.3	4.71	3.77	20.4	15.7
August	2005	27.5	33.0	22.0	1008.3	70.2	0.0	8.6	5.7	16.5	3.88	3.10	21.7	16.7
	2006	27.1	33.5	21.2	1007.4	71.1	0.0	8.0	4.5	12.4	3.34	2.67	21.8	16.8
	2007	27.3	33.2	21.9	1007.5	69.3	0.0	9.9	4.4	11.4	3.52	2.82	21.7	16.7
	2008	27.8	33.7	22.4	1006.4	71.0	0.0	9.2	6.3	15.0	4.24	3.39	21.7	16.7
	2009	27.4	32.9	21.8	1008.3	68.7	0.0	10.1	9.0	17.7	5.16	4.13	21.7	16.7
	2010	28.6	34.1	23.7	1006.8	72.8	0.0	10.0	7.7	16.2	5.08	4.06	21.6	16.7
September	2005	26.0	32.4	20.1	1012.0	66.1	0.0	8.3	6.7	16.7	3.91	3.13	22.0	17.0
	2006	26.0	32.0	20.1	1011.6	67.4	0.0	9.7	5.4	15.6	3.64	2.91	21.9	16.9
	2007	25.6	31.0	20.3	1011.2	68.2	0.0	10.2	4.5	12.0	3.35	2.68	21.8	16.8
	2008	26.7	32.6	21.2	1010.9	65.7	0.0	10.3	7.2	16.1	4.36	3.49	21.6	16.6
	2009	25.8	31.7	20.2	1011.6	66.8	0.0	10.2	10.1	18.6	5.19	4.16	21.5	16.5
	2010	26.9	32.3	21.5	1010.7	68.5	0.0	10.2	7.8	15.9	4.68	3.74	21.3	16.4
October	2005	22.2	28.3	16.0	1015.5	65.4	1.0	8.4	7.6	17.8	3.52	2.82	22.3	17.2
	2006	22.9	29.4	17.2	1013.3	65.1	4.1	10.3	6.1	15.7	3.36	2.69	22.3	17.2
	2007	23.2	29.7	17.5	1015.0	73.1	3.1	9.6	3.8	11.3	2.87	2.29	22.3	17.2
	2008	22.5	28.3	17.1	1016.1	70.0	92.2	10.3	6.5	14.8	3.53	2.83	22.3	17.2
	2009	24.1	31.1	18.0	1012.6	68.0	0.8	10.1	8.8	16.7	4.44	3.55	22.2	17.1
	2010	24.7	31.3	19.0	1013.4	66.5	0.0	9.7	8.2	15.7	4.32	3.46	22.0	17.0
November	2005	17.7	23.8	12.2	1017.3	63.8	0.0	10.2	12.4	21.8	3.97	3.17	24.4	18.8
	2006	17.0	23.8	10.9	1017.3	71.3	8.9	9.6	7.5	15.7	2.98	2.38	24.4	18.8
	2007	18.7	26.2	12.1	1017.2	65.5	1.0	9.4	6.6	15.7	2.84	2.27	24.3	18.7
	2008	18.8	25.9	12.7	1017.3	66.8	2.0	9.9	5.7	12.9	2.73	2.19	24.3	18.7
	2009	18.1	25.4	11.7	1015.8	66.0	0.3	10.0	9.6	16.8	3.47	2.78	24.3	18.7
	2010	20.0	27.6	13.9	1015.8	74.0	1.0	8.3	6.1	11.6	3.00	2.40	24.3	18.7
December	2005	14.8	21.9	9.2	1017.6	70.0	2.5	6.9	8.0	17.0	2.57	2.06	19.0	14.7
	2006	13.1	19.9	7.5	1020.9	69.3	62.2	9.4	8.8	18.4	2.70	2.16	19.2	14.8
	2007	14.1	21.7	8.0	1018.4	65.8	0.5	9.2	6.9	15.5	2.39	1.91	19.2	14.8
	2008	15.1	22.7	8.8	1018.0	62.4	3.1	9.3	6.9	14.5	2.46	1.97	19.1	14.7
	2009	16.0	23.3	10.2	1016.0	62.1	5.1	9.2	11.0	20.5	3.26	2.61	19.2	14.8
	2010	15.3	23.6	8.5	1015.4	59.5	1.0	9.0	9.3	15.7	2.81	2.25	19.2	14.8



Modélisation des flux énergétiques et hydriques d'un système « Sol-Orangeraie » (Nord Sinaï, Egypte)

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Projet AIRD-STDF (2011-2013)

Un programme de recherche conjoint France-Egypte, financé par l'AIRD-STDF[*] et intitulé « *Gestion durable des impacts négatifs sur l'agriculture et l'écosystème Sol, associés à une irrigation prolongée par des eaux de mauvaise qualité* », a été initié en 2011 (Braudeau et Zaghloul, 2010). Une partie du projet est relative aux calculs des flux énergétiques et hydriques du système « Sol-Plante-Atmosphère » en utilisant le modèle hydrodynamique Kamel® (Braudeau et al., 2006).

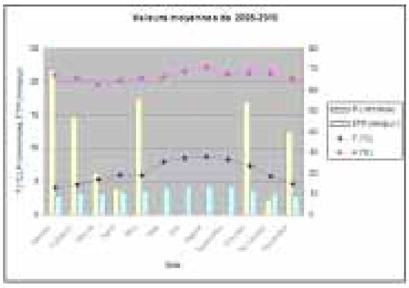
Ce modèle mécaniste simule le bilan hydrique d'un sol donné avec une nouvelle approche qui rend compte de l'organisation du sol (pédostructure, horizon, pédon, unité cartographique élémentaire des sols) et de ses interactions avec l'eau. Les variables d'entrée du modèle sont les évapotranspirations potentielle et réelle du couvert végétal, les caractéristiques hydro-structurales de chaque horizon de sol (courbe de retrait, potentiel hydrique, conductivité hydraulique), l'épaisseur de l'horizon et la distribution racinaire du couvert végétal dans le sol.

Objectif

Valider les sorties du modèle Kamel®, à savoir la teneur en eau et le potentiel hydrique du sol, ce qui permettra la quantification des besoins en eau et du stress hydrique du couvert végétal pour des applications telles que l'irrigation de précision, la prévision de la productivité, la vulnérabilité aux parasites, le risque d'incendie et l'évaluation du cycle des éléments nutritifs.

Sites d'étude du projet

Climat du Nord Sinaï



Evolution de la température moyenne de l'air, des précipitations incidentes, de l'humidité relative de l'air, de l'évapotranspiration potentielle (station météorologique « El-Arich, Egypte », 31,08°N-33,83°E, 31 m). Valeurs moyennes sur la période 2005-2010 à partir de mesures journalières.

Orangeraie d'El-Salam, Nord Sinaï

Orangeraie irriguée par des eaux en mélange contrôlé (eaux de drainage, eaux du Nil et eaux d'épuration). Superficie d'environ 80 ha. Située à 155 km, au nord-est du Caire.

Données climatiques calculées

	ETo (mm.d⁻¹)	ETR (mm.d⁻¹)	Rg (MJ.m⁻².d⁻¹)	Rn (MJ.m⁻².d⁻¹)
Janvier	1.79	2.28	21,6	16,7
Février	3.03	2.42	22,1	17,0
Mars	3.07	2.46	22,2	17,1
Avril	3.39	2.68	21,6	16,7
Mai	3.42	2.74	20,8	16,1
Juin	3.99	3.19	21,5	16,6
Juillet	4.26	3.41	20,5	15,8
Août	4.20	3.36	21,7	16,7
Septembre	4.19	3.39	21,7	16,7
Octobre	3.67	2.94	22,2	17,1
Novembre	3.16	2.53	24,3	18,7
Décembre	2.70	2.16	19,2	14,8
Jan.-déc.	3.48	2.79	21.61	16.65
annuel	1271.5	1017.2		

Rayonnement global et net, évapotranspiration potentielle et réelle dans l'orangeraie d'El-Salam. Valeurs moyennes calculées par la formule de Penman-Monteith et le coefficient cultural, sur la période 2005-2010, à partir de mesures journalières. Il s'agit des données d'entrée du modèle Kamel®.

Données pédo-climatiques à acquérir sur le site

Mesures à l'aide du rapport de Bowen : évapotranspiration réelle, bilan d'énergie, flux de chaleur latente et sensible, humidité relative de l'air, température moyenne de l'air (psychromètre), vitesse du vent (anémomètre), rayonnement global (pyranomètre) et rayonnement net (bilanmètre), température du sol (sondes thermiques) (Nizinski et al., 2009).

Perspectives

Le présent travail permettra la mise en place d'un modèle mécaniste « Sol-Plante » par couplage du modèle Kamel® avec des modèles de complexité moyenne (SiSPAT, ISBA) ou des modèles très complexes (STIC, ICARE).

IRD Institut de recherche pour le développement — AIRD — Bioemco — STDF

Braudeau E., Zaghloul A. 2010. Sustainable Management of Adverse Impacts on Farming and Soil Ecosystem Associated with Long Term Use of Low Quality Irrigation Water. Joint Innovative Projects Fund, STDF-AIRD. Joint Research Project, Scientific Document, 48 p.

Braudeau E., Mohtar R.H., 2006. Modeling the swelling curve for packed soil aggregates using the pedostructure concept. Soil Sci. Soc. Am. J., 70: 494–502.

Nizinski J.J., Galat-Luong A., Galat G., Dingkuhn M., Fayse O., 2009. Evapotranspiration réelle et résistance du couvert d'une savane à Loudetia arundinacea (bassin du Kouilou, Congo-Brazzaville). Climatologie, 6: 33-45.

(*) AIRD Agence inter-établissements de recherche pour le développement — STDF Science and Technology Development Fund