

Project Progress report

Impact of small hill reservoir on water flow and nitrogen transfer in Mediterranean agricultural catchment (Kamech, Cap Bon, Tunisia)



as a part of the IAEA's
Coordinated Research Project CRPD1.20.10
*Strategic Placement and Area-Wide Evaluation of Water Conservation Zones in
Agricultural Catchments for Biomass Production, Water Quality and Food Security*

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1. Introduction

Fresh water scarcity and therefore the access to safe water is the critical problem to manage in the arid climatic regions. Water as part of the larger ecosystem on which biodiversity depends is a vital factor for socio-economic development. Precipitation, converted to soil and groundwater and thus accessible to vegetation and people, is the dominant pre-condition for biomass production and social development in drylands. The amount of available water, equivalent to the water moving through the landscape, fluctuates between the wet and dry periods. Catchment harvesting through water and soil conservation measures have largely contributing to avoid water lack by enhancing water storage capacity, infiltration capacity.

The overall objective of this project is to achieve two issues related to small dam building in Mediterranean region upstream catchments. The first issue concerns the effects of dams on water exchanges between surface and shallow aquifer. The second issue concerns the nitrogen cycle and more specifically the denitrification occurrence in such context. These issues are highly dependant since nitrogen and denitrification fluxes in the catchment depend on hydrological fluxes.

2. Project activities

For the last period of the project second year, we have intended:

- **Activity 1:** Inventory of land uses variations
- **Activity 2:** Monitoring of isotopic and chemical composition of water from different components of the system with different sampling time step.
- **Activity 3:** Water budget of the Lake Kamech.
- **Activity 4:** Monitoring of the spatial distribution of nitrogen concentrations (nitrate, nitrite and ammoniac)
- **Activity 5:** Monitoring of flood events during the rainy season

These activities have been achieved through three tasks:

1. Field work consists mainly in collecting and analyzing surface water (runoff, lake), groundwater and rainfall water during the different periods of the hydrological cycle: low-water runoff, high-water runoff and flood events. For the lake water budget set up, all hydrologic input and output from the lake will be sampled during the year and analyzed for isotopic composition, major elements and nitrogen elements (NO_3 , NO_2 , NH_4^+). Since water flowing into the lake can come from the wadi runoff, the direct rainfall and the groundwater, these three hydrologic components will be

sampled. Meanwhile, water loss from lake into groundwater can occur by exfiltration through the dam and by infiltration through the lake bed. Groundwater sampling at different locations around the lake will allow define the isotopic composition of each of these two types of losses. For nitrogen characterization, aliquots will be taken from water sampled for isotopic analysis. Furthermore, groundwater and wadi heads will be sampled throughout the catchment. These samples will be analyzed for NO_3 , NO_2 , NH_4^+ and for major elements. Temperature, redox potential, electrical conductivity and pH will be measured on each sampled.

uses have been identified in each parcel of the watershed during field trip.

2. Laboratory tasks: Major elements, among which nitrate will be analyzed at the LRAE-ENIS with a liquid phase chromatography. Water stable isotopes will be analyzed at the LRAE-ENIS. The LRAE is equipped with Direct Liquid Stable isotopes analysis equipment (Los Gatos). Nitrate, nitrite and ammoniac concentrations will be measured in the laboratory of the INAT Institute with a standard protocol.

3. Discussion and interpretation of data, results: These activities will lead to a sensibility study of the model (water budget and evaporation), and to a critic of the sampling protocol to adjust it to results and to scientific publication.

3. Preliminary scientific outcomes of the project

The next part of this report presents preliminary results of the project.

3.1. Land uses

The first assessment that could be noticed through the land uses inventory is that natural vegetation has almost disappear on the Kamech catchment.

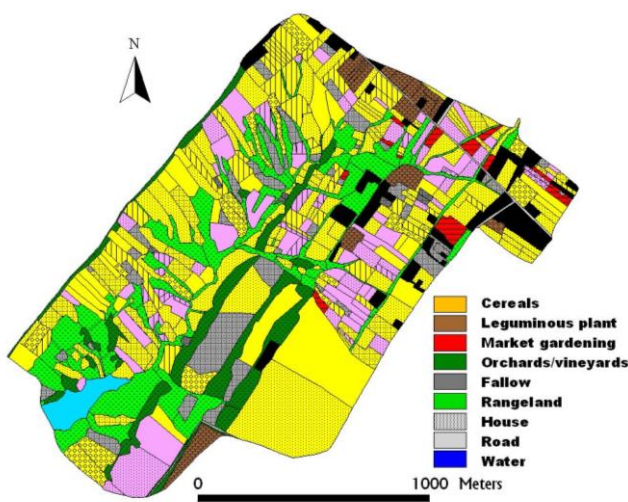


Figure 1a: Land uses 2009-2010

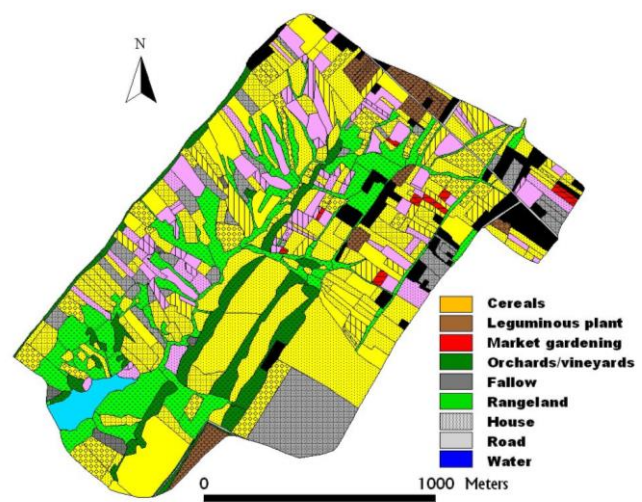


Figure 1b: Land uses 2010-2011

Land use (Table 1) is characterised by a high fragmentation with 0.52 ha mean parcel area and a high spatial variation. However, at the watershed scale, land uses are quasi constant from year to year.

Table 1 : Land uses in the Kamech watershed

	2009-2010			2010-2011		
	Nbre of parcels	Surface (m ²)	%	Nbre of parcels	Surface (m ²)	%
Cereals	226	1204557,8	45,8	228	1203171,09	46,4
Legumineus plants	85	364048,7	13,8	90	437483,434	16,9
Market gardening	14	33371,8	1,3	11	15887,133	0,6
Orchards/Vineyards	16	81603,0	3,1	16	74709,718	2,9
Fallow	52	179319,3	6,8	37	131255,538	5,1
Rangeland	87	587193,4	22,3	87	587193,366	22,6

Water of the lake supplied irrigation uses at a volume varying between 20 000 and 50 000 m³ per year in relation with the amount of rainfall. The lake is supplying water for industrial production of tomatoes and peppers practiced by approximately 20 farmers on little parcels of 0.63 ha mean dimension. Extension of irrigated surface varies from one year to another ranging between 5 and 20 ha and is continuously increasing due to the involvement of the lake in the local agriculture system and due to the state encouragement to develop irrigated farming. Manure remains the main fertiliser used by farmers

3.2. Characterisation of the different waters of the catchment

Stable isotope fingerprint of precipitation: Each rain event has been sampled and plotted in the diagram of δD vs $\delta^{18}O$ (Fig.3). 119 rain events has been sampled and analysed. Event data vary between 0,1 and -13,73‰ VSMOW for ^{18}O and between -4.93 and -89,3‰ VSMOW for Deuterium. The local meteoric line (Figure 2a) is obtained by the monthly weighted isotopes contents by imposing a 8-slope. The D-excess (+12) indicates the depleted eastern Mediterranean influence (+22) and the Atlantic influence (+10).

Seasonal variations (Figure 2b) show more depleted values during cold season. The more depleted value is obtained for January rains and could be explained by a seasonal effect related to lower temperatures of atmospheric vapour condensation. Enriched values are explained by low rainfall amount and evaporation effect. The isotopic signal is therefore thermodependant with an enrichment during hot season (-0,71‰) and a depletion during cold season (-7‰).

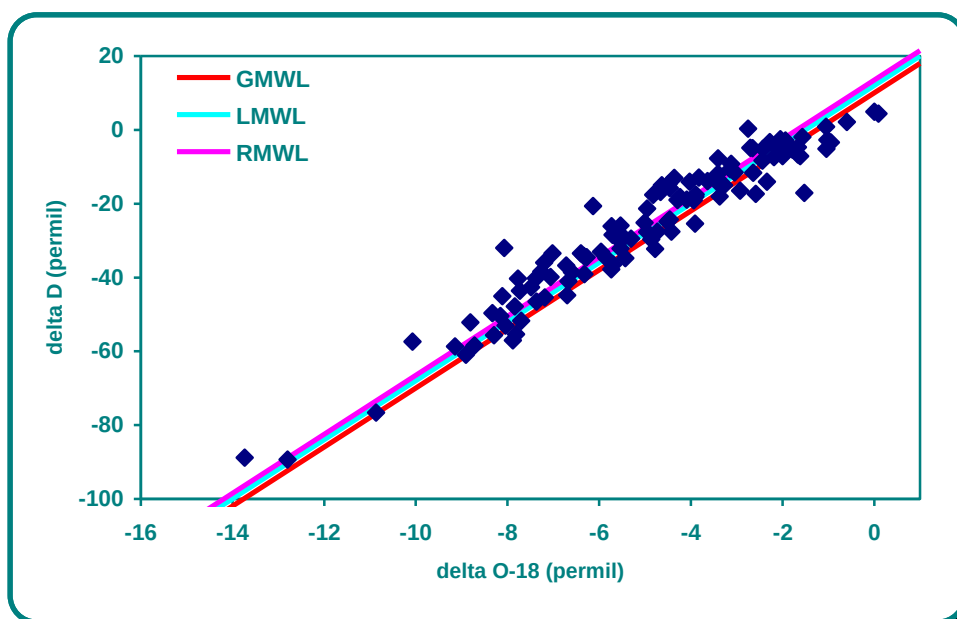


Figure 2a : $\delta^2\text{H}$ vs $\delta^{18}\text{O}$ (‰ VSMOW) for Kamech precipitation

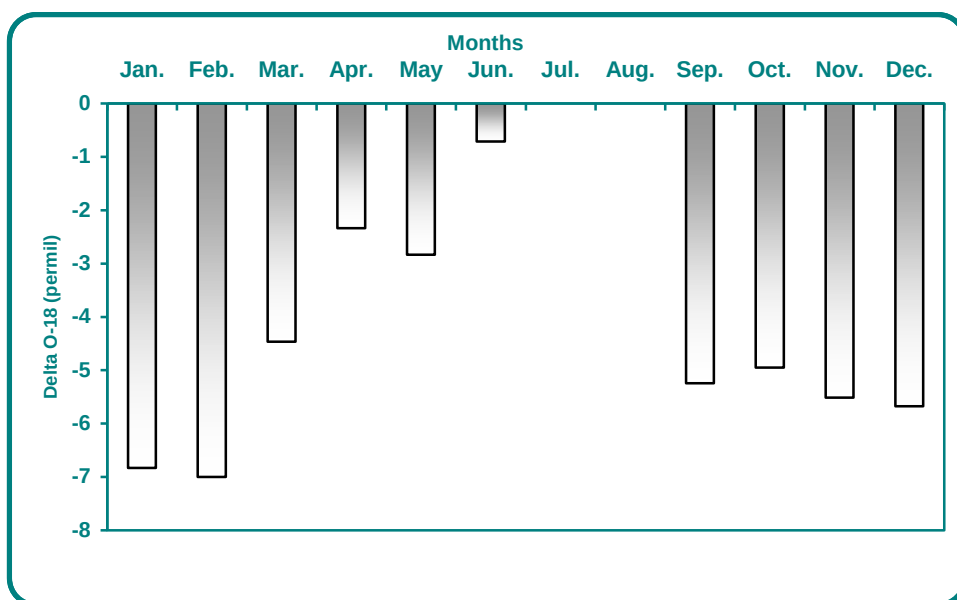


Figure 2b : Seasonal variation of $\delta^{18}\text{O}$ (‰ VSMOW) for Kamech precipitation

Major elements (Table 2) in rainfall water show not typical high value of HCO_3 due to the probable presence of dust in the atmosphere and/or in pluviometer container. High chloride values are explained by the proximity of the sea.

Table 2 : Major elements of precipitation

	Cl	NO_3	SO_4	HCO_3	Na	K	Mg	Ca
Mean	7	5	3	18	5	1	1	7
Max.	11	17	5	36	7	2	1	13
Min.	3	0	2	11	3	0	0	4

Stable isotope fingerprint of groundwater: Groundwaters have been distinguished according their location: upslope, around the lake and downstream the dam (Figure 3).

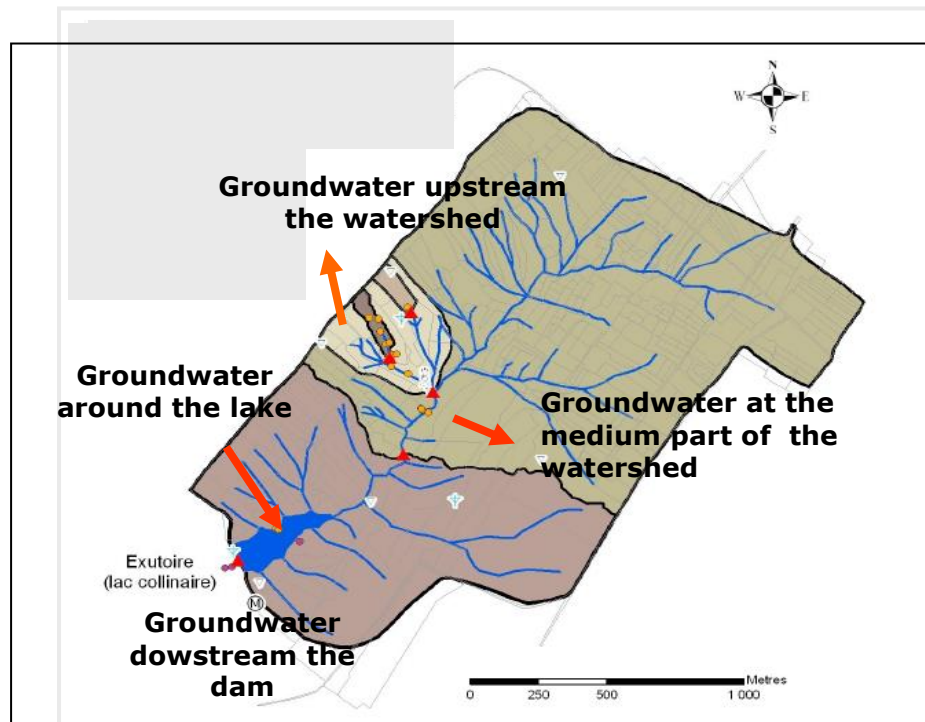


Figure 3: Groundwater distribution over the Kamech watershed

Stable isotopes contents vary between 0 and -6 ‰ VSMOW for ^{18}O and between 0 and -35 ‰ VSMOW for Deuterium. Range of stables isotopes as obtained by a monthly sampling protocol indicate a stable signal weakly influenced by hydrological processes (recharge – evaporation) (Fig.4). However, no seasonal variation has been clearly observed (Fig.5).

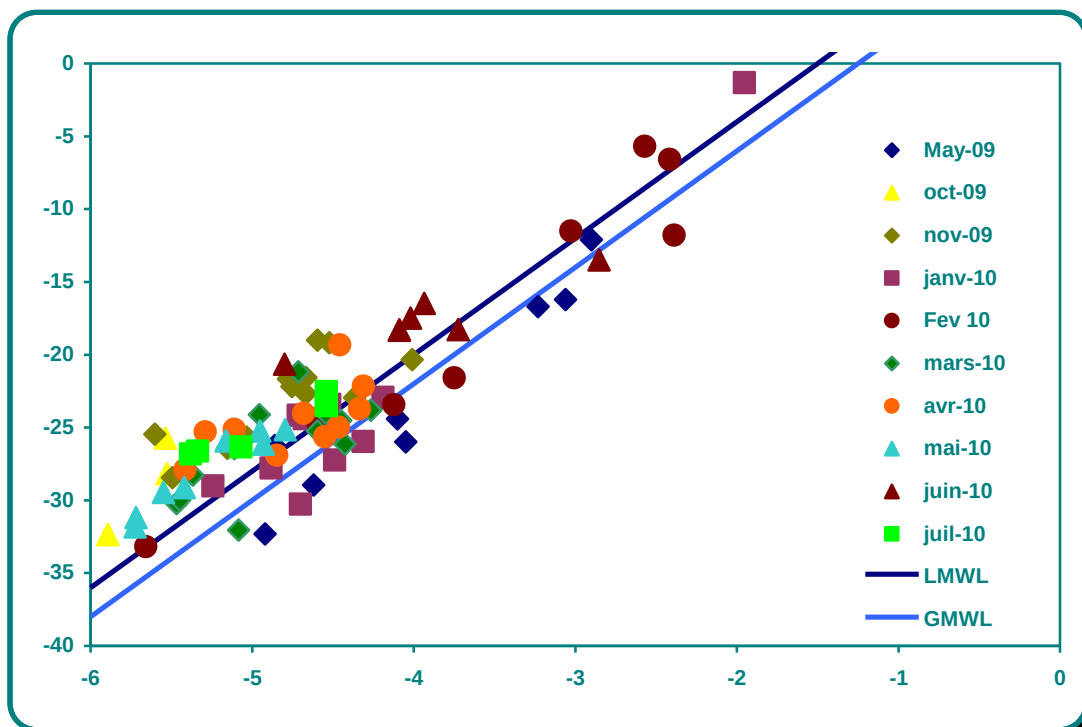


Figure 4: D-O diagram for the Kamech groundwater

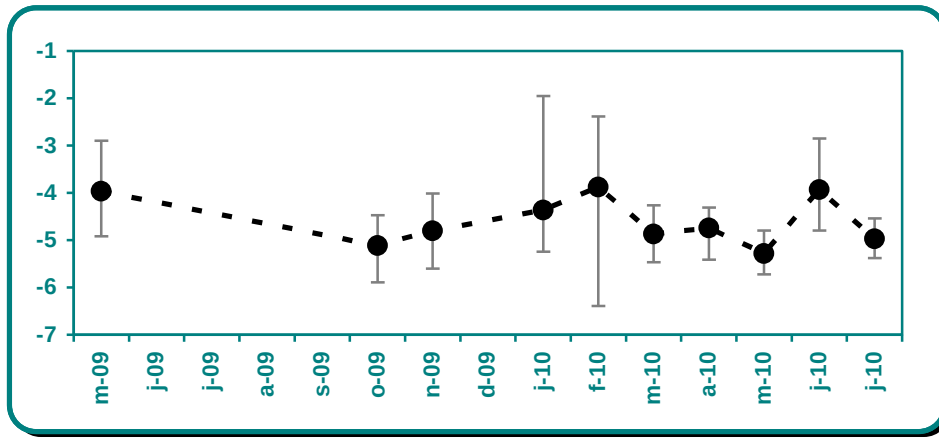


Figure 5: Seasonal variation of mean stable isotopes contents of Kamech groundwater

The isotopic signal of groundwater downstream the dam is close to that of lake but less enriched indicating that the recharge is a mixing between overflow, releases and infiltration. Stable isotope signal of piezometers located around the lake are used for the isotope budget and considered constant at a monthly scale.

Major elements (Table 3) indicate a mixed facies slightly chlorided to sulphated calcic. No temporal variation could be noticed. A very large spatial heterogeneity is observed and could be explained by particular hydrogeological context since groundwater is lodged in little independent aquifers of different geological formations and variable depths.

Table 3 : Major elements of groundwaters

Date	Cl ⁻	NO ₃ ⁻	SO ₄ ²⁻	CO ₃ ²⁻	HCO ₃ ⁻	Na ⁺	K ⁺	Mg ²⁺	Ca ²⁺	TDS
oct-09	667	4	758	1	316	409	10	122	250	2620
nov-09	496	22	875	4	316	364	14	146	211	2612
janv-10	806	3	662	0	220	419	4	131	245	2644
Feb- 10	839	1	515	0	262	438	6	107	215	2432
mars-10	580	10	817	0	299	328	6	136	269	2525
apr-10	472	9	766	0	287	357	5	147	193	2320
may-10	893	2	535	0	274	563	0	114	154	2696
june-10	753	0	580	0	259	457	1	111	147	2411
july-10	916	0	562	0	298	482	0	123	186	2657
Mean	713,6	5,7	674,4	0,6	281,2	424,1	5,1	126,3	207,8	2546,3

Stable isotope fingerprint of streamflow: 55 samples collected when runoff is occurring each week (sept.09 – Jan.12). Stable isotopes contents vary between -7 and +3 ‰ VSMOW for ¹⁸O and between -37 and +0,2 ‰ VSMOW for Deuterium. Isotopes contents of streamflow (Fig.6) have the same range of precipitation signal indicating that direct runoff is the main contribution to

streamflow. A more detailed study of this data coupled with flood events sampling planned for the next high-water season will permit to focus on flood processes of the catchment.

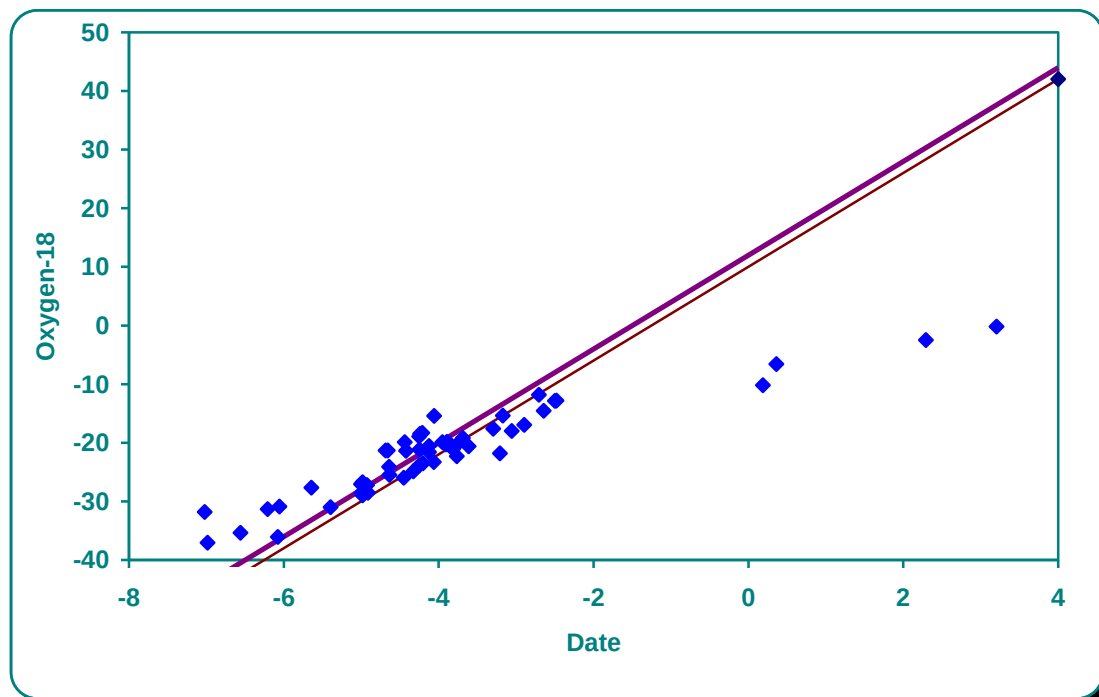


Figure 6: D-O diagram for the Kamech runoff

Seasonal trend is clearly noticed in relation with rainfall signal (Fig.7).

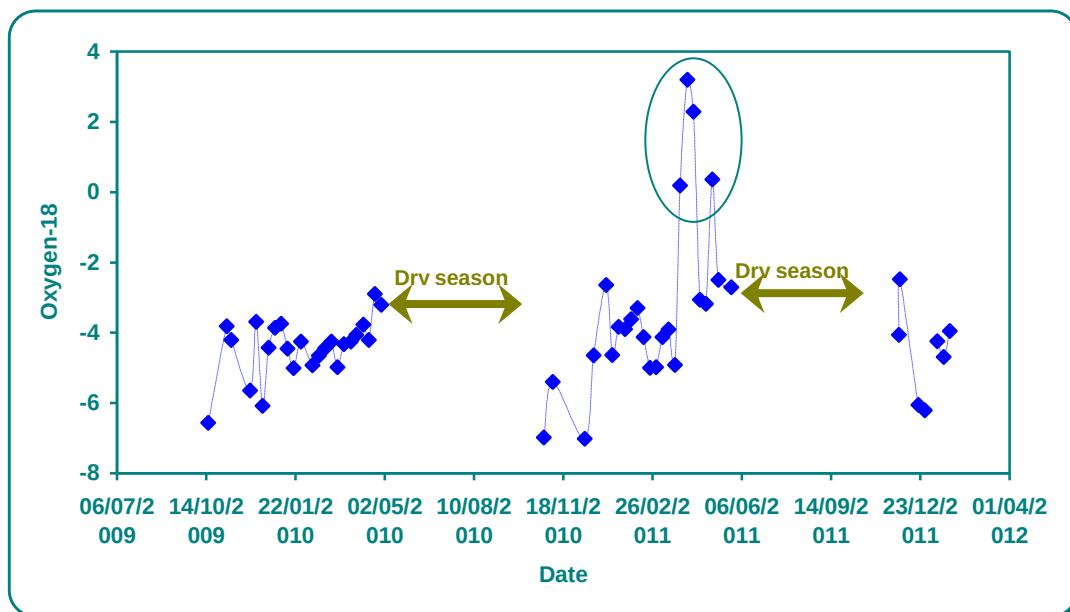


Figure 7: Seasonal variation of mean stable isotopes contents of Kamech runoff

Stable isotope fingerprint of the Kamech Lake: 115 samples collected from the Lake each week (sept.09 – Jan.12). Stable isotopes contents vary between -3,83 and +4,79 ‰ VSMOW for ^{18}O and between -18,74 and 21,08 ‰ VSMOW for Deuterium. Data plot clearly indicate the “evaporation effect” with a 4-slope line (Fig.8).

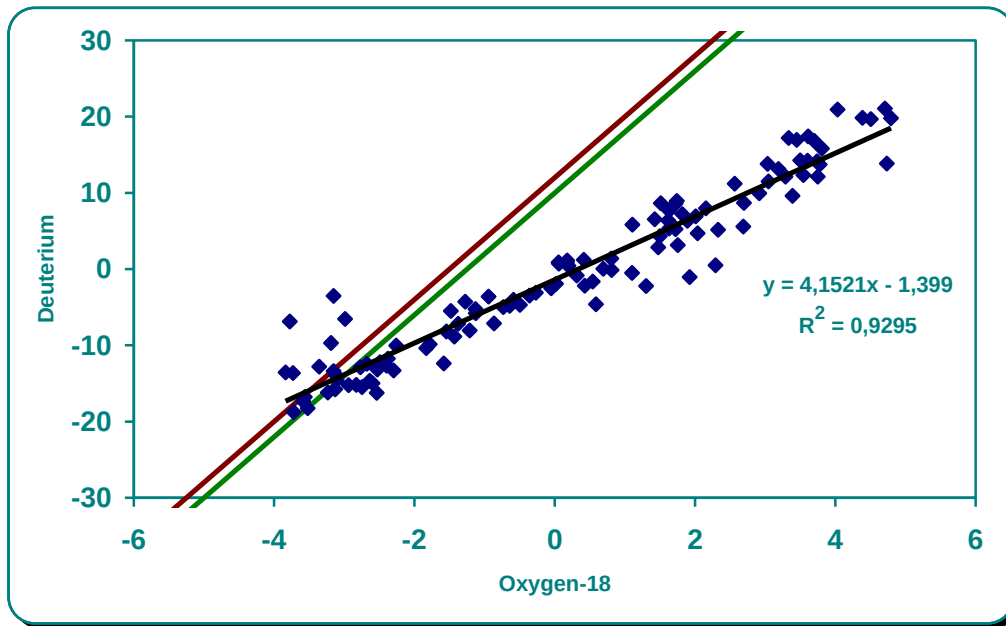


Figure 8: D-O diagram for the Kamech Lake waters

Stable isotopes contents of the lake waters (Fig.9) show clear seasonal trend closely related to the volume variation. During the high-waters season, stable isotopes signal is fluctuating in relation with precipitation, streamflow overflow and probably releases volumes. However, during the low-waters season, the signal is continuously enriched due to evaporation effect that became the most important term of the water balance.

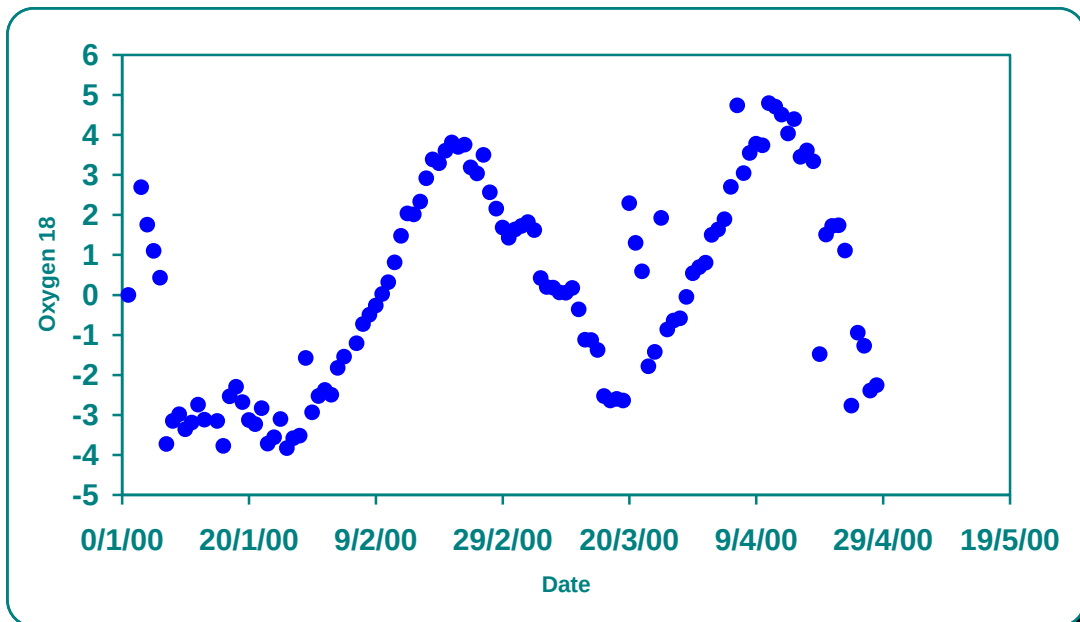


Figure 9: Seasonal variation of mean stable isotopes contents of Kamech runoff

3.3. Water budget of the storage lake

Net exchanges between groundwater and the lake, defined as $V_{L-G} = V_{ex} - V_i$, had been estimated indirectly by the balance between the lake volume variation and the difference between input and output terms .

At an annual scale, for an initial volume of 46780 m³ at the beginning of the year (sept-2009) and for a quite rainy period (09/09-12/10), exchanges fluxes between the lake and the underlying aquifer are estimated at 69 000 m³

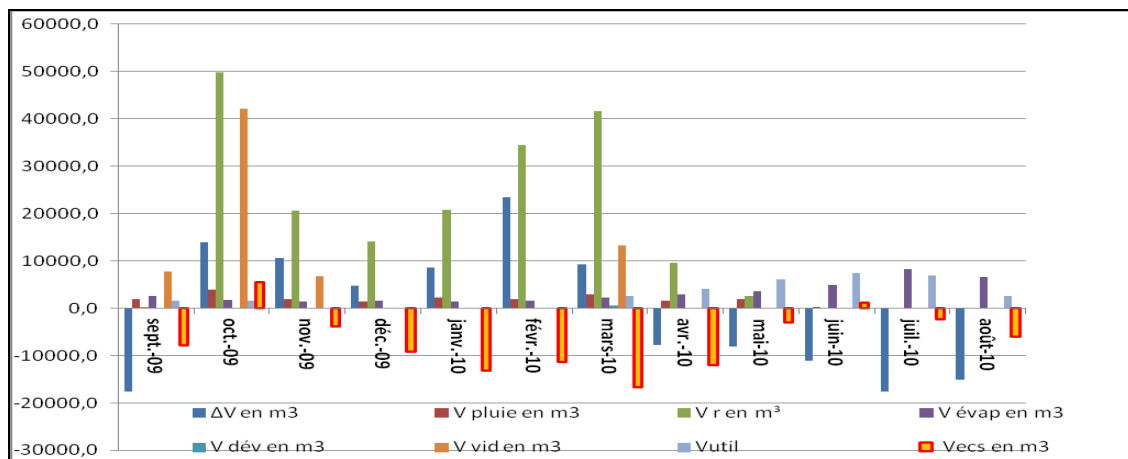


Figure 10: Main water balance terms for the Kamech lake (1/09/2009 to 30/06/2010)

The water budget established for a monthly time interval during the 2009-2010 hydrological year reveals that exchanges between the lake and the underlying aquifer are mostly negative (Table 4) that means that in most of the time the lake is recharging groundwater.

Table 4: Monthly Water budget of the Kamech Lake (m³)

Months	Sept-09	Oct-09	Nov-09	Dec-09	Jan-09	Feb-09
Net Exchanges	-7 871.4	5 511.4	-3 775.9	-9 256.4	-13 129.2	-11 352.4
Months	Mar-10	Apr-10	May-10	Jun-10	Jul-10	Aug-10
Net Exchanges	-16 603.1	-11 944.4	-3 047.3	11 19.1	-2 413	-5 984.8

October and June (Figure 10) are the only months during which exchange volume are dominated by groundwater exfiltration. During October, high diversions volume had induced abrupt drop of the storage level what therefore became below the water level of the underlying aquifer. This difference induced an inversion of fluxes between the two water masses. The weekly water budget highlighted that the inversion of flux immediately follow the diversion period. In the other hand, during the dry season, inflow decrease and the storage level also decreases. When this level becomes below the water level, the flux inversion occurs and the groundwater exfiltrates toward the lake.

The isotopic balance had been applied at daily; weekly and monthly scales. First results confirm that the infiltration is the dominant process controlling lake-aquifer exchanges. Daily calculations indicate that water releases, carried out to protect the dam, highly disturb the system lake-

groundwater equilibrium and led to the inversion of water fluxes from the aquifer to the lake. On the other hand, when excepting these short periods, maximum of net exchanges volume are estimated for March when the storage level is at its maximum. The water budget indicates that approximately 69 000 m³ had infiltrated into the underlying alluvial aquifer during the 2009-2010 water year. However, this alluvial aquifer had supported the lake level during high diversions periods and during dry season by supplying about 10 000 m³ to the lake.

3.4. Nitrogen forms in water masses

According to last RCM discussions and to expert recommendations, a simplified schema was considered to be investigated (Figure 11).

This schema presents rain-fed cultivated plots and a succession of humid zones the latest being supplied by the Kamech pond surrounding saturated area. Like in Estonia biomass production of the considered wet zones are not of main interest for food production but are delivering crucial ecological services, thus, given first results on nitrogen characterisation of different compartments of the catchment, they seem to play a very important role in the mitigation of nutrient fluxes from the crop production that is located upland. This scheme, if identified, could help be design mitigation solution for N fluxes from rain-fed fields and villages by natural and artificial wet zones what could be of high interest for stakeholders and local authorities.

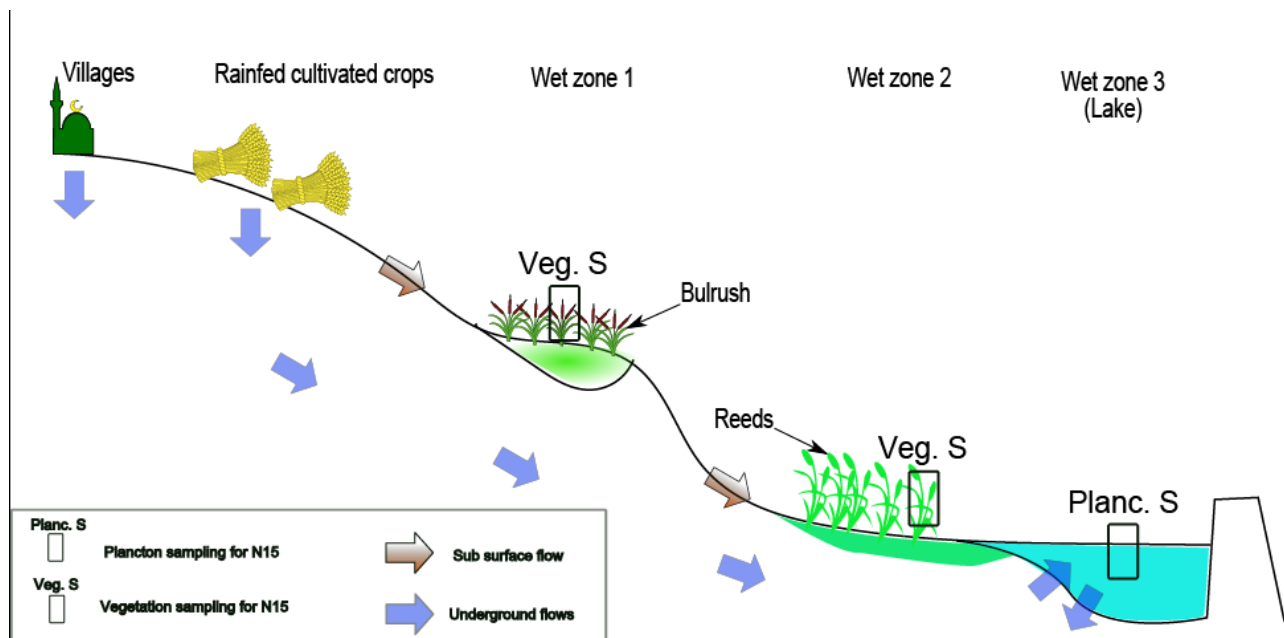


Figure 11: Mitigation of nitrogen fluxes by natural and artificial wet zones

In the case of the Kamech catchment, fertilizers and manures are used to enhanced soil productivity. Quantities depend on rainfall amount, crop type and soil type.

According to a field investigation, local doses vary between 100 and 200 Kg/ha of ammonitrate applied on parcel after rain and 100 kg/ha of DiAmmonium Phosphate distributed over the year.

The nitrogen forms have been obtained out according to the following sampling and analyses protocol:

- Sampling has followed the protocol implemented for isotopic study : water is collected from surface runoff, from groundwater and from the lake, once a month.
- Water is analysed for mineral nitrogen forms and for chloride.
- When the runoff is occurring in the catchment, water is sampled at four points (experimental parcel, ravine, slope station and wadi station).
- Sampling is hand made in 1 liter polyéthylène bottles.
- Conductance, temperature and pH are measured in situ by a field conductivimeter (consort K 912) and pHmeter (consort C 933).
- Bottles are taken to the laboratory in the same day and immediately filtered at 0,45µm.
- Samples are then conserved at 4°C. Analyses are carried out during the next 48 hours.
- Analyses had been carried out on a spectrophotometer DR/4000 (MODELES 48000 and 48100) with a direct reading and calibrated for several parameters with corresponding standards, used with visible spectra and tungsten-halogen lamp (320 à 1100 nm) (Hach Campany, 2001).
- Ammonium is analysed according to blue Indophénol method (Rodier et al., 1997).
- Nitrates are analysed by spectrophotometry of moleculal absorption (Rodier et al., 2005).
- Nitrites are analysed by spectrophotometry of moleculal absorption (Int. Norm 1984)
- Chlorides are analysed by Mohr method (Rodier et al., 2005)
- Analyses have been carried out in the Laboratory of Sciences and Technics of Environment (LSTE) of the INAT in collaboration with LRAE and IRD teams.
- Precision has been determined according to the protocol of incertitude estimation of physico-chemical analyses (AFNOR XP T 90-220, 2003) based on the GUM (Guide to the expression of Uncertainty in Measurement) for which each samples is analysed three times.
- Incertitude ranges are 8-68%, 8-67%, 70-77% and 0,3-7,5% respectively for nitrate, nitrite, ammonium and chloride. These large ranges should be taken in account during results discussion.

- Temporal and spatial variations are considered significant when greater than these incertitude values.

First data concerned pH and conductance measurements (Table 5). Conductance variation is greater than measurement incertitude estimated at 4% and therefore considered as significant, this parameter is included in the APC analysis.

Table 5: pH and conductance data

Site	pH	σ	Conductance ($\mu\text{S.cm}^{-1}$)	σ
Piézo 1	7,14	0,13	5616	200,7
Piézo 2	7,14	0,05	5148	95,4
Piézo 3	7,12	0,1	5514	104,1
Piézo 4	7,19	0,08	2536	895,9
Piézo 5	7,22		2450	
Piézo 7	7,27	0,17	2540	418,3
Piézo 8	7,08	0,08	2340	28,3
Piézo 11	7,09	0,06	3664	70,2
Piézo 12	7,09	0,08	3815	154,7
Piézo 13	7,35	0,04	2488	88,4
Piézo 14	7,16	0,5	1647	32,3
Piézo 17	7,11	0,15	1827	25,8
Piézo 18	7,05	0,29	2523	394,4
Piézo 19	7,39	0,12	894	214,3
Piézo 20	7,29	0,15	2257	416,6
Piézo 21	7,26	0,15	1706	479,5
Piézo 22	7,24	0,16	1439	194,7

Chloride data (mg/l) (Table 6) indicate that:

- Values measured during observation period are high and variable and are above OMS recommended values (between 500 mg/l and 600 mg/l for agriculture).
- Highest concentrations (Fig. 12) are observed upstream the watershed at piez1 ($1407,6 \pm 218,2$ mg/l), piez2 ($1344,6 \pm 124,6$ mg/l) and piez3 ($1452,3 \pm 120,2$ mg/l).
- Other upstream piezometers have low values ranging between 230 and 430 mg/l (piezometers 4, 5, 6, 7, 8, 9, 10 and 13) and between 600 and 750 mg/l (piez. 11 and 12).
- Lower values are observed at the wadi level (piez. 14 : $269,3 \pm 91,1$ mg/l) and piez. 20 ($461,4 \pm 93,3$ mg/l).
- ➡ Chloride concentrations present a downstream decrease trend without temporal variation.
- ➡ The lowest value is recorded for the piezometer 19 (58,2 mg/l) close to the lake.

Table 6: Nitrogen forms and chloride data (mg/l)

Site	[Cl ⁻]	s	[NO ₂ ⁻]	s	[NO ₃ ⁻]	s	[NH ₄ ⁺]	s
Piézo 1	1407,6	12,27	0,002	0,004	0,19	0,40	0,054	0,003
Piézo 2	1344,6	12,27	0,002	0,003	1,17	2,12	0,035	0,003
Piézo 3	1452,3	12,27	0,005	0,006	0,96	0,74	0,338	0,005
Piézo 4	331,7	12,27	0,034		2,71		0,04	
Piézo 5	422,8	12,27	0,003		0,00		0,055	
Piézo 6	370,5	12,27	0,000		0,00			
Piézo 7	434,6	12,27	0,003	0,005	6,26	3,40	0,047	0,005
Piézo 8	365,6	12,27	0,005	0,014	8,43	6,48	0,024	0,014
Piézo 9	232,9	12,27	0,000		0,00			
Piézo 10	259,6	12,27	0,002		12,27	17,35	0,059	
Piézo 11	752,5	12,27	0,244	0,021	7,44	6,03	0,023	0,021
Piézo 12	602,3	12,27	0,024	0,018	18,30	9,60	0,028	0,017
Piézo 13	341,9	12,27	0,039	0,008	2,39	2,68	0,226	0,008
Piézo 14	269,3	12,27	0,002	0,009	3,56	3,59	0,039	0,009
Piézo 17	141,4	12,27	0,071	0,017	43,45	17,00	0,035	0,017
Piézo 18	289,5	12,27	0,011	0,005	5,58	5,40	0,412	0,005
Piézo 19	58,2	12,27	0,002	0,003	1,25	0,97	0,049	0,003
Piézo 20	461,4	12,27	0,004	0,003	3,91	1,83	0,073	0,003
Piézo 21	234,4	12,27	0,011	0,019	5,04	2,73	0,175	0,019
Piézo 22	202,1	12,27	0,005	0,003	2,06	1,33	0,096	0,003

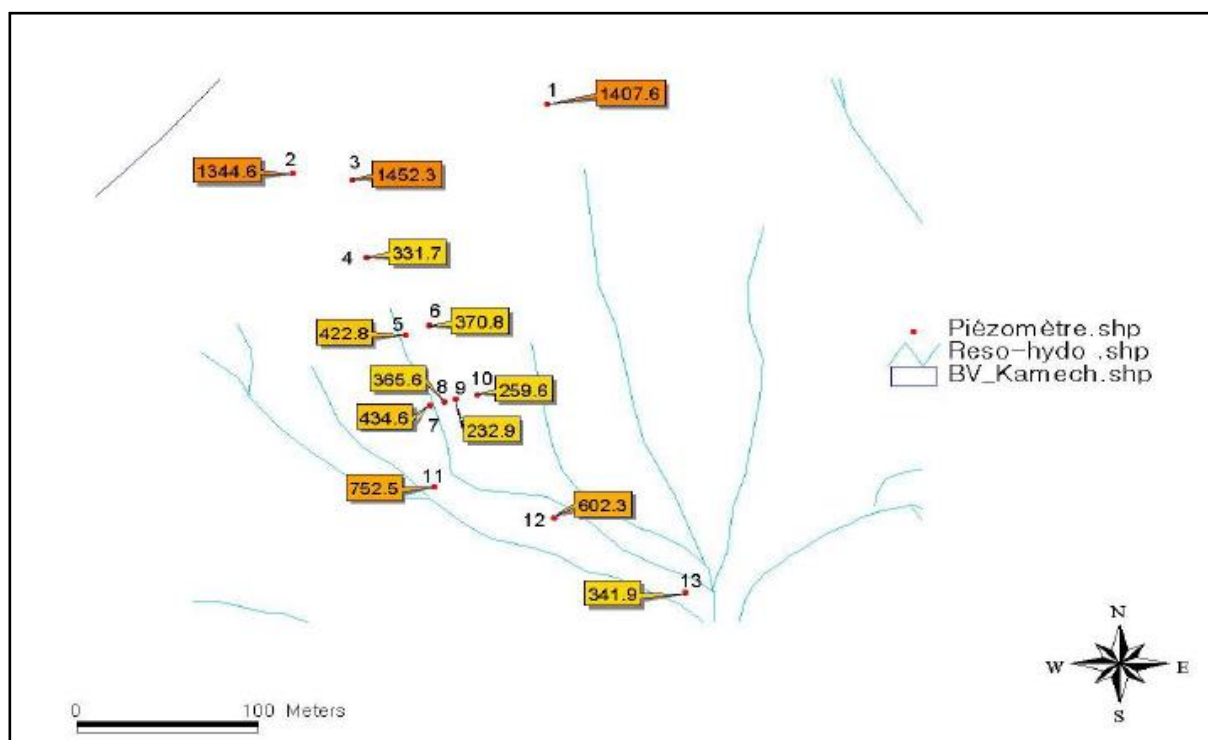


Figure 12: Chloride distribution on Kamech groundwater

Nitrate and ammonium data (Table 6) indicate that:

- Spatio-temporal variations of nitrite mean concentration are in trace level with low standard deviation indicating that nitrite contents can be considered as constant for the basin.

- Spatial variation of mean ammonium concentration and their standard deviation are very low. Ammonium variations are considered of natural levels.
- Spatio-temporal variation of nitrates contents are significant with a large range of 0,19 to 43,45 mg/l (Figure 13).
- High standard deviations indicate a large dispersion of values around mean values.
- Lowest nitrate concentrations are recorded upstream the watershed : piez1 ($0,19 \pm 0,40$ mg/l), piez2 ($1,17 \pm 2,12$ mg/l), and piez3 ($0,96 \pm 0,74$ mg/l).
- Highest values are observed in piez12 with a mean value of $18,30 \pm 9,6$ mg/l.
- Wadi values are quite low and range around 4 mg/l (Piez14 : $3,56 \pm 3,59$ mg/l ; piez20 : $3,91 \pm 1,83$ mg/l).
- Low nitrate content at surface water could be explained by denitrification phenomenon and transformation of nitrates in vapour phase nitrogen. Around the lake, nitrate contents are also low (piez18: $5,58 \pm 5,40$; piez19: $1,25 \pm 0,97$ mg/l; piez21: $2,73 \pm 0,175$ g/l and piez22 : $2,06 \pm 1,33$ mg/l).
- The nitrate content of lake water is about $2,71 \pm 1,59$ mg/l.

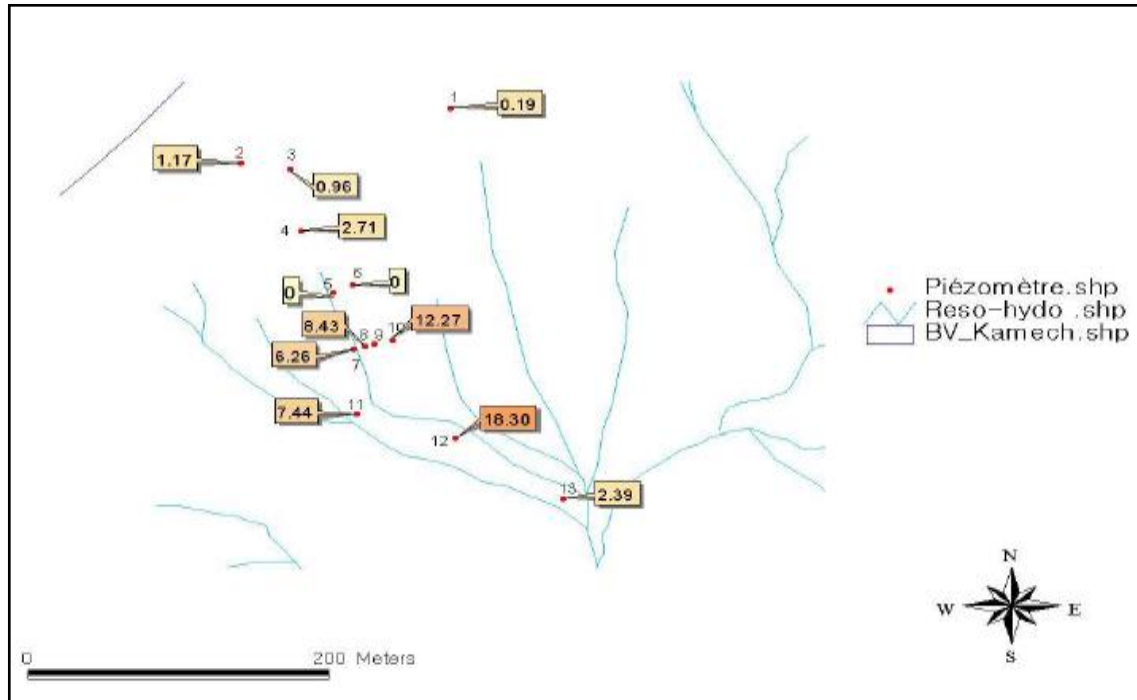


Figure 13: Nitrate distribution in groundwater of Kamech watershed.

The molar ratio nitrate/chloride (Figure 14) could be interpreted in terms of nitrate evolution: If nitrate contents decrease due to dilution, the ratio remains constant otherwise, if the ratio decreases, nitrate is reduced either by denitrification or by vegetation absorption (Caubel-Forget et al., 2000).

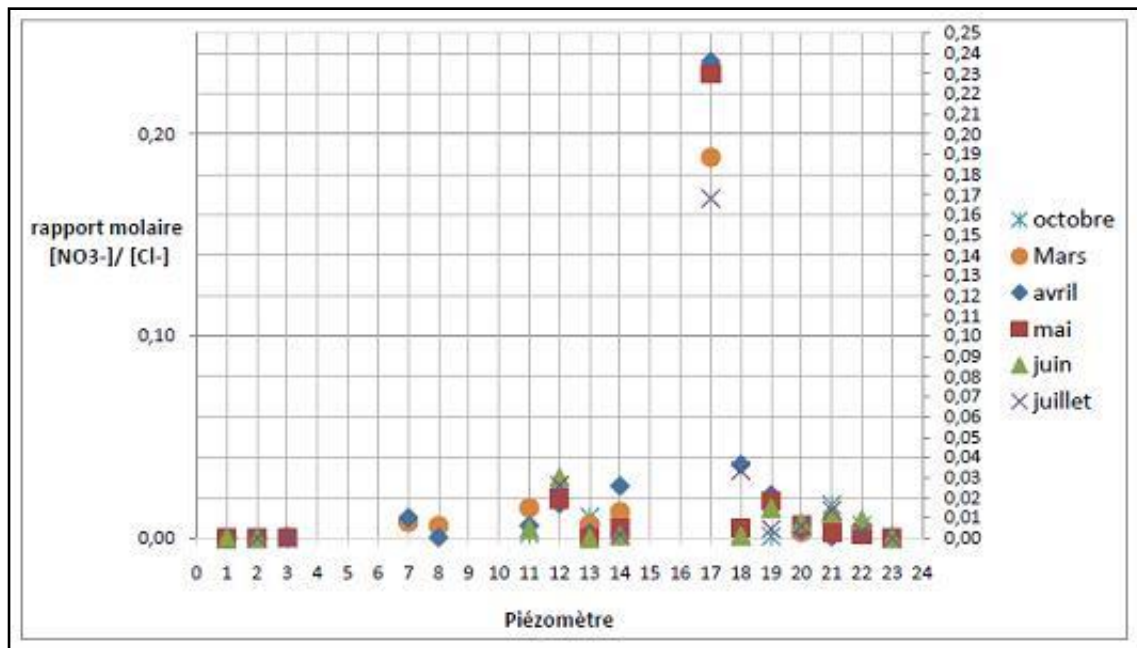


Figure 14: Molar ratio nitrate/chloride for the Kamech groundwater

Most samples are characterised by constant nitrate/chloride ratio what indicate that dilution is the main process controlling groundwater quality. Dilution is probably explained by groundwater mixing with precipitation and lake water mixing by precipitation and runoff. Decrease of some ratios for other sites is explained by denitrification and/or vegetation adsorption.

3.4. Flood processes

Two floods have been sampled during the 2011-2012 hydrological season in two different stations of the watershed (Fig.15). Data are still been discussed for interpretation.

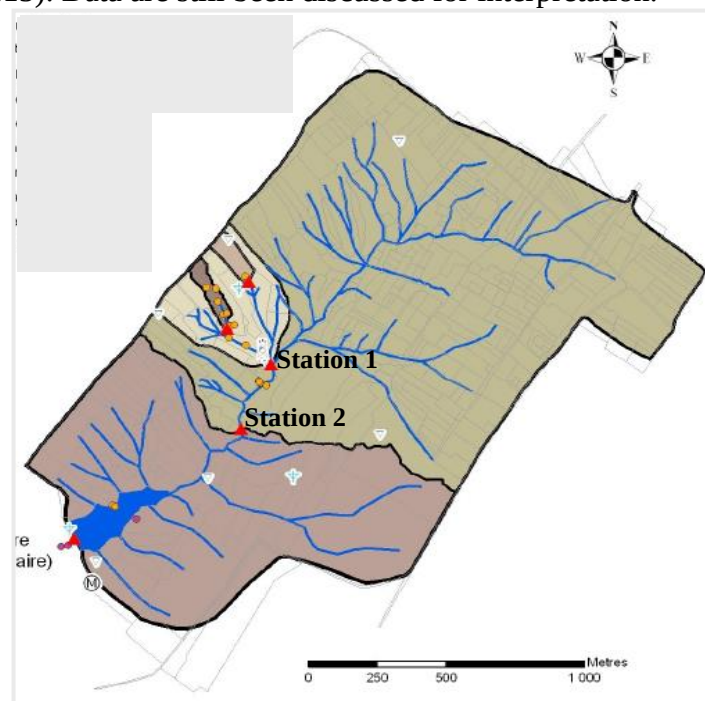


Figure 15: Localisation of flood sampling

Table 7: Flood data for the Station 1 (0,16 km2) and Station 2 (1,82 km2).

Date	N°	Q l/s
29/1/12 19:39	VSP1	0,126
30/1/12 7:33	VSGP2	9,013
30/1/12 7:37	VSGP3	11,633
30/1/12 7:45	VSGP4	14,674
30/1/12 7:55	VSGP5	18,157
30/1/12 8:03	VSGP6	22,103
30/1/12 9:09	VSGP7	46,151
30/1/12 11:59	VSGP8	86,499
30/1/12 12:29	VSGP9	163,810
30/1/12 13:17	VSGP10	112,707
30/1/12 13:51	VSGP11	64,401
30/1/12 16:19	VSGP12	20,071
31/1/12 9:03	VSGP13	3,434

Date	N°	Q l/s
29/1/12 20:06	OS1G-P	5,95
30/1/12 7:54	OS2G-P	18,10
30/1/12 8:11	OS3G-P	30,72
30/1/12 8:14	OS4G-P	36,28
30/1/12 8:22	OS5G-P	41,11
30/1/12 8:42	OS6G-P	82,92
30/1/12 8:59	OS7G-P	157,75
30/1/12 9:08	OS8G-P	375,14
30/1/12 10:56	OS9G-P	523,01
30/1/12 11:56	OS10G-P	668,73
30/1/12 12:42	OS11G	1095,45
30/1/12 12:57	OS12G	1787,69
30/1/12 13:19	OS13G	1503,27
30/1/12 14:01	OS14G	847,61
30/1/12 16:29	OS15G	214,15
31/1/12 9:21	OS16G	36,28
31/1/12 10:41	OS17G	31,63

3.5. Outcomes

Main outcomes of this activity are:

- The isotopic balance applied at daily, weekly and monthly scales confirms that water resources at the catchment scale, is constituted by the surface lake and by an underlying alluvial aquifer mainly recharged by the lake infiltration.
- Daily calculations indicate that water diversions, carried out to protect the dam, highly disturb the lake-groundwater system equilibrium and led to the inversion of water fluxes from the aquifer to the lake.
- When excepting these short periods, maximum of net exchanges are estimated for March when the storage level is at its maximum.
- The water budget indicates that approximately 79 000 m³ had infiltrated into the underlying alluvial aquifer during the 2009-2010 water year.
- The alluvial aquifer had supported the lake storage during high diversions periods and during dry season by supplying about 10 000 m³ to the lake.
- Nitrate is the main nitrogen form which was observed in all the hydrologic compartments of the Kamech catchment. However, nitrate concentrations remained rather low. Low nitrate concentrations in lake can have two reasons: 1) when considering the low nitrate concentration in wadi flow, the first reason would be that nitrate transport in Kamech catchment from soils to the wadi and then to the lake does not occur because the source of nitrate in soils is limited due to a complete absorption of available soil nitrate by plants. 2) the second reason would be that nitrate is transported to the lake by surface runoff and that

denitrification or aquatic plant absorption in lake would decrease nitrate concentrations resulting in low nitrate concentrations. At this stage we must recall that wadi was sampled only during base flow periods. So any nitrate transported by surface runoff during storm events could not have been observed with the protocol we followed.

4. Project workplan

During the next period of the project, we intend to carry following activities:

Water conservation issues: The first activity will aim to refine data interpretation, in particular, the time residence of groundwater should be assessed. Therefore, sampling and analysing for isotopic/chemical data will be continued and some tritium analyses will likely be carried out. Outcomes and results will be published in an international scientific paper.

Nitrate issues: According to the last RCM (July 2012, Vienne, Austria), technical support will be ensured by IAEA for nitrate isotopes analyses (capacity building and analyses support in a recognized laboratory). The second activity will aim to complement nitrogen form data by $\delta^{15}\text{N}/\delta^{13}\text{C}$ analyses in soil/vegetation over the watershed. This activity will be carried out according to following workplan:

- 2 sampling campaigns : during the dry period (spring 2013) and during the wet period (winter 2012);
- Sampling sites : 5 samples for each of the 6 land use types (6) ~ 30 points for each sampling campaign;
 - Sampling protocol (in the upper layer) : vegetation, litter and soil : 0-10 and 10-30 cm;
 - 8 samples around the lake edge ;
 - Vegetation from the lake : floating or rooted vegetation;
 - Soil/vegetation from « hotspots » according to the same sampling protocol.

5. Conclusion

Main conclusions based on activities outcomes are :

- Groundwater over the catchment is quite homogeneous with temporal variation indicating that the recharge, even if it exist, remains limited: quantification of such a recharge should be investigated
- Water resources at the catchment scale, is constituted by the surface lake and by an underlying alluvial aquifer mainly recharged by the lake infiltration: the management of such an aquifer should be planned.

- Spatio-temporal variations of nitrogen forms (nitrite, ammonium and nitrate) are very low : the source of nitrate in soils is limited and/or nitrate are transferred by surface runoff.
- Natural vegetation has almost disappear on the Kamech catchment but different land uses remains quite constant except for irrigated fields which extension vary according to climate conditions.