British Journal of Applied Science & Technology
14(6): 1-8, 2016, Article no.BJAST.24098
ISSN: 2231-0843, NLM ID: 101664541

SCIENCEDOMAIN *international*
www.sciencedomain.org

Arid Climate in the Sirba Basin in Burkina Faso: Causes for Better Decisions in Land Use Planning

Yélézouomin Stéphane Corentin Somé[1*], Lamine Dango[2] and Gado Djibo Abdouramane[3]

[1]Département de Géographie, Université de Koudougou, 01 BP 6820 Ouagadougou 01, Burkina Faso.
[2]International Institute for Water and Environmental Engineering (2iE), Burkina Faso.
[3]Wetlands International, Mali office, BP 5017 Hamdallaye ACI 2000, Mali.

Authors' contributions

This article was designed by author YSCS based on master's thesis of author LD. Author LD supervised it. Author YSCS wrote the first draft. Data collection and analysis were done by authors YSCS and LD. The literature searches and result discussion were done by authors GDA and YSCS. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/BJAST/2016/24098
Editor(s):
(1) Xu Jianhua, Department of Geography, East China Normal University, China.
Reviewers:
(1) Milena Moteva, University of Architecture, Civil Engineering and Geodesy, Bulgaria.
(2) Evangelia N. Sossidou, Hellenic Agricultural Organization-Demeter, Greece.
(3) Keqiang Yang, Shandong Agricultural University, China.
Complete Peer review History: http://sciencedomain.org/review-history/13566

Original Research Article

Received 4th January 2016
Accepted 20th February 2016
Published 5th March 2016

ABSTRACT

The issue of climate change highlighted the dynamics of the global ecosystem especially in the atmosphere component. The perception of this phenomenon at the local level, in the villages, from serious scientific studies conditioned decisions on land use. Yet, these scientific truths evolve with time and their demonstration is different according to the space extent covered. It follows some decisions whose effectiveness has to be adapted in the light of the functioning of the considered phenomenon. Thus, it arises the issue of data quality in decision making in land planning. In the basin of the Sirba, there is an exacerbation of water-related conflicts, and this could be due to aridification that would be the consequence of a downward trend in precipitation. An explanation that governs the decisions made on water resources management in the basin of Sirba. The sole objective of this study is to check the veracity of aridification of the climate in the Sirba basin and the responsibility of the precipitation in this process. The methodology is based on a statistical

**Corresponding author: E-mail: corentin.some@gmail.com, some_y@yahoo.fr;*

analysis of the spatiotemporal evolution of the climate aridity and variables associated with it such as precipitation, temperature, number of rainy days and potential evapotranspiration. The results showed that the current aridification is not the fact of a decrease in precipitation, nor a reduction of the number of rainy days. It rains more and more often in the Sirba basin. However, the temperatures were higher as well as the losses by evapotranspiration. This interpretation different from the aridification phenomenon, draw the attention towards a revision of the solutions envisaged for solving of the problem. The decisions to reduce the evaporation should be preferred for more efficiency.

Keywords: Aridity; precipitation; climate change; temperature; Sirba basin; Burkina Faso.

1. INTRODUCTION

Sirba is a transboundary river shared between Burkina Faso and Niger Republic. It is tributary of the Niger River. The study area covers about 2300 km^2 located in Burkina Faso and represents over 80% of the entire area of Sirba watershed. It is also an experimental zone used by many NGOs such as IUCN, Global Water, and AGRHYMET to address main challenges related to the phenomena of the aridity of the Sahelian climate. It is located between 12°30' and 13°13' N latitude and between, 0°29' and 1°00' E longitude (see Fig. 1) [1]. In Burkina Faso, it extends over three provinces: Komandjari, Yagha and Gnagna and it covers 45% of the municipality of Mansila, 10% of the municipality Boundoré, 80% of the municipality of Foutouri, 60% of the municipality of Gayéri, 20% of the municipality of Bartiebougou and 45% of that of Liptougou [2].

The Sirba basin undergoes an increase of water-related conflicts. This exacerbation of conflict sets here a problem of space planning. A space badly understood, badly interpreted, badly evaluated by a community, a society, is badly used and therefore badly lived. Thus, it is the problem of territory planning that leads to these conflicts bound to integrated water resources management [3]. The evolution of water resources in the soudano-Sahelian zone is a more and more worrisome question both in the economic development and for the future

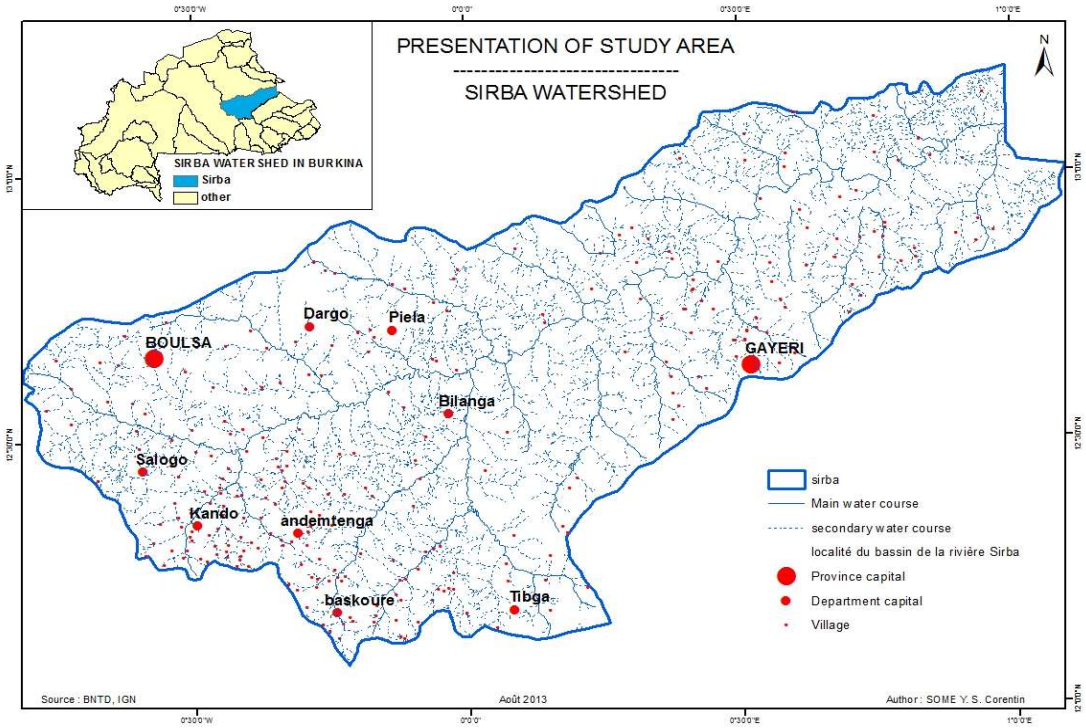

Fig. 1. Sirba basin geographical situation

of populations in terms of health, drinking water, food security [4]. Therefore, it is important for a sustainable development to envisage a study of the phenomenon in this area, to understand factors of dynamics and identify the best space planning which will reduce in a subsequent way of conflicts.

In this perspective, some studies were carried out and with questionable elements. In 1987, Carbonel and Hubert asserted that the renewal of the resources in the available water, results from precipitation [5-7]. Then, Mahé pointed that the precipitation decrease in all Western and Central Africa during decades 1970 and 1980 [8]. The reduction of the resource in water is thus bound to a reduction in the precipitation and in the number of rainy days [9].

Base on these scientific truths, spatial planning will take a direction, that of fighting against the reduction trend in precipitation, by the policy of artificial rain (SAAGA program) [10], (2004) and the construction of 2100 dams among which 380 create permanent water reservoirs [11].

The agricultural sector is partially a trigger to desertification [12], justified the policy of three fights: fight against abusive logging, fight against wandering animals and the fight against bush fires [13]. Additionally, there is a growing demand for water due to population increase and economic activities also consume water [14]. Lastly, the diversity of water use in the basin is presented like a exacerbating factor of conflicts related to water. RISACC confirms that in the Nakambé basin the reduction in water resources led to an aggravation of the problems related to water resources availability and management added to a constant increase in demand and a diversification which still accelerating [4].

In summary, it is the climate change that can be considered, at the level of the study region, as cause of this water resource reduction under a natural process.

If the relevance of the questioning of precipitations in the global analysis is undeniable because of their positions in the management of the resource, it remains important to make a thorough analysis of their effectiveness in of the study area [15].

The research question which emanates from this situation is: do the climatic tendencies lead to a reduction of the precipitation and the number of rainy days in this Sahel region?

2. OBJECTIVES OF THE STUDY

The global objective of this study is to contribute to a better understanding of Sirba watershed in order to promote sustainable management of water resources and ecosystem-services through better spatial planning. This knowledge production will be directed towards the phenomenon of the climatic aridification.

The aridification is understood in this context as climate process where water supply is lower than the losses; this results in a change in the structure and balance of ecosystems where the vegetation is an effective biomarker.

The specific objective is to verify the effectiveness of climate in the Sirba basin. In this perspective, the aridification is understood as a climatic water balance with negative trend.

It must involve both the inputs and consequently the amount of water recorded in the watershed, and losses taken into account in the context of this study, through evaporation that is related to the biophysical activity of which the most conspicuous and measurable determinants are the evaporation, the potential evapotranspiration and the temperature.

To consider the recurring results in the scientific literature hinting at a decrease of the quantity of water precipitate, the hypothesis is that there is a process of aridification going on in the basin related to a decrease of the number of rainy days and to the precipitated amount of water.

3. MATERIALS AND METHODS

3.1 Materials

The material used in this study is of two types, ancillary data and software.

Ancillary data are composed of climate data, satellite image and a geographic database.

- The ancillary data: They are composed of climatic data and geographical database. Climatic data are sourced from the Head office of the National Meteorology and are constituted by series on monthly rainfall, the number of rainy days, the minimal,

maximal and average temperatures, the potential evapotranspiration (PET) of all the ten (10) meteorological stations over the period 1980 to 2011.
- Geographic database is obtained from the National Topographic Bank of Data of Burkina Faso (BNDT) of the Geographic Institute of Burkina (IGB)

- Software: the software used in this study, are XL-Stat for statistical processing and ArcGIS and ArcView for geographic data processing.

3.2 Methods

The methodology is based on an analysis of the spatiotemporal evolution of the climate aridity.

For that purpose, climate variables which influence most the contributions of water by the atmosphere (input) and the departures of water in the atmosphere (output) were retained. Moreover, a synthetic index of aridity acting as balance assessment between the inputs and outputs is added to the previous variables.

These variables are:

- The quantity of rainfall over a year and the number of rainy days in a year were used for inputs. These are obtained from ten (10) stations.
- The average monthly potential evapotranspiration (PET) and the monthly average temperatures were used for outputs. The PET data were obtained using the Penman method [16].

There are several criteria and index of evaluation of the aridity: diagram ombrothermique of Gaussen, index of Köppen, index of Thornthwaite, index of Gaussen and Bagnouls, index of Budyko, index of the UNEP, index of De Martone in the monthly and annual declension [17,18].

In this research work, it is the monthly index of aridity of Martone that was used for the data availability in the Sirba region.

The variables used are: precipitation, number of rainy days, the temperature, the PET and the aridity index.

For each variable, annual averages were calculated, exported and spatialized by interpolation from the kriging method. The interpolation was necessary because there is not enough observation stations in the considered site. In order to have these data in the study area, the synoptic stations of Burkina were put in contribution. For the aridity index, average monthly precipitation and temperature were calculated. The aridity index was previously computed using the formula of De Martonne

$$I = P * 12 / (10 + T)$$

where, P is the monthly precipitation, and T is the mean monthly temperature.

Based on the results of interpolation, each spatial interpolation unit may have a variable value.

For the study area, the mean monthly annual, averages of the various pixels of interpolation were calculated and later used in the temporal analysis. The data resulting from the interpolation are thus synthesized to give an average of the variable over the entire study area. These data are transformed into standardized values before being used to draw the curves. Then, the curves of linear trends over the period were derived from plotted curves.

4. RESULTS

The results of this study showed that the trend of precipitation increases both from the point of view of precipitated rains and the number of rainy days. From Fig. 2, it is noted that the slope of the trend line of rains is positive with a slope of 0.04 over the 32 years. It is the same for the trend line of the number of rainy days which is also positive with a slope of 0.06 largely higher than to that of the quantities of precipitated water recorded.

There is thus a trend increase of the contributions of water by the atmosphere. This result is in opposition to the findings of Sircoulon and Mahé according to whom the precipitation decrease in all Western and central Africa during decades 1970 and 1980 [19,8]. This difference may - be due to spatial scaling effect analysis or also to the temporal position of the study. Indeed, it is well about a period not considered in this study and about space covering a region that covers several climatic zones including the desert up to the wet equatorial zones.

The trends of ETP and temperatures are also high. The trend lines plotted over the 32 years for the PET and the temperature are also positive with respective slopes coefficients of 0.01 and 0.07 (Fig. 3).

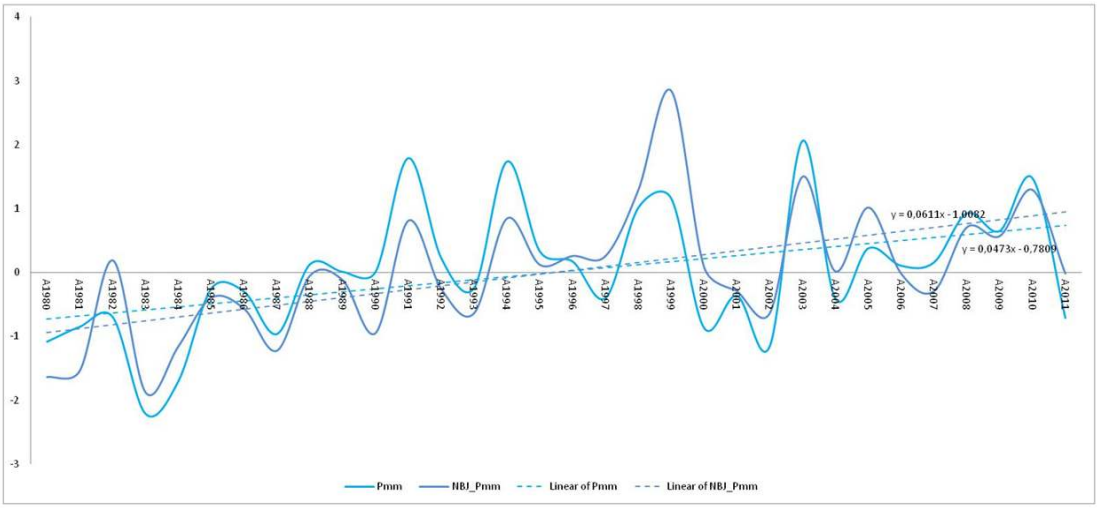

Fig. 2. Temporal evolution of precipitation and number of rainy days on Sirba basin

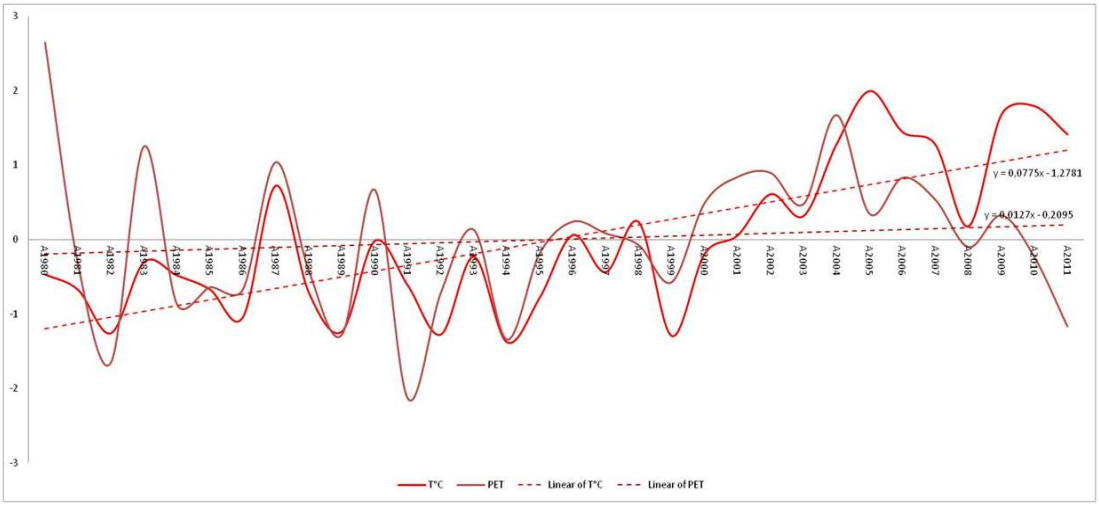

Fig. 3. Temporal evolution of temperatures potential evapotranspiration

The results from Fig. 3, showed that the slope of the temperatures is very strong compared to that of precipitation and the number of rainy days. It explained a more important increase of the temperatures compared to the number of rainy days and the precipitated quantities of water. This result also means that the losses by evaporation are also increasing trend. So, the quantities of water taken back by the atmosphere are also increasing**.** This result is in accordance with those of [20], who concluded in an increase of the temperatures during the last decades and its impact determining on the seasonal rainfall regime in the watershed on N'zi (Bandama). It is also in keeping with [21], who speaks about coherence of simulation models on intensification of the hydrological cycle in a future climate, warmer than a current climate.

Both types of variables showed an increasing trend, thus it is important to consider the time evolution of the aridity index. The aridity index connects rainfall and temperatures. Its trend allows having a synthetic trend of the phenomenon.

The more the value of the index is low, the more the environment is dry. The trend line of De Martone aridity index in the Sirba basin (Fig. 4) highlights a decreasing trend of the index value. Indeed, the slope of the trend curve is negative (-0.003).

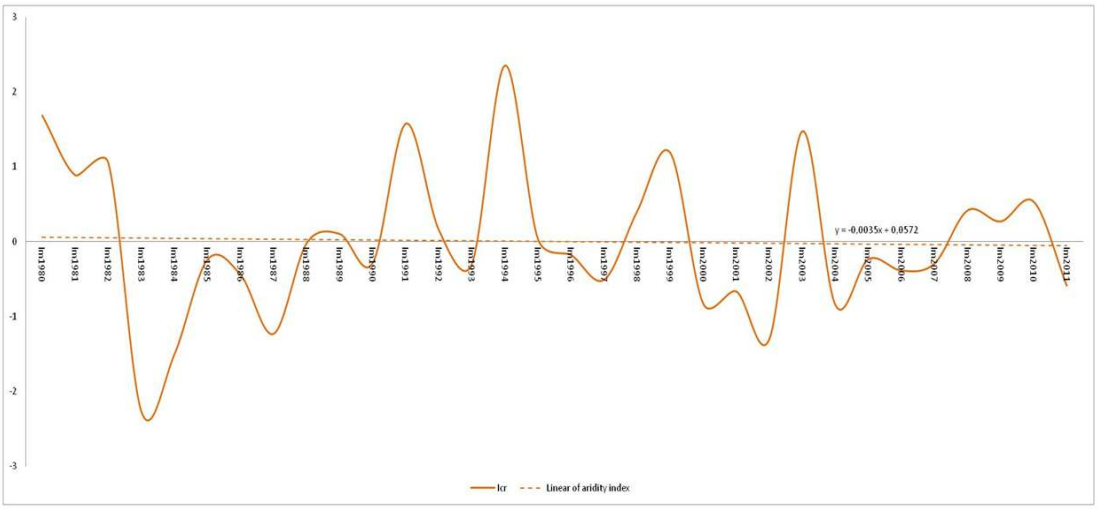

Fig. 4. Temporal evolution of aridity index on Sirba basin

It means clearly that if the trend still continues in this way, the zone will be drier and drier. This is in compliance with the results of [5]. One notices a process of aridification with regard to this result. Thus, it can be said that the inputs are lower than the outputs. The process of aridification comes not from a reduction of the availability of water resources or the decrease in precipitation nor the number of rainy days, as numerous publications tended to emphasize on. In this environment, the problem is rather connected to a strong increase of the temperatures and thus of the evaporation.

5. CONCLUSION

The results of this study have shown that in the Sirba basin, he falls more and more rainwater and it rains more often, as shown by the trends of the precipitations and the number of rainy days, from 1980 to 2010. He also highlighted the trend of rising temperatures and evapotranspiration; two output terms of water balance. This study has put into relation the two terms of the water balance to see if the outputs are higher than the inputs or not. The result is that the Sirba basin is experiencing an aridification process. This means less water for human activities than before. With these results, the solutions to fight against the problem of lack of water must be reviewed.

In fact, the complexity of questions of water resources and the perpetual dynamics in such sources can lead to the implication of some variables which can get up inaccurate. But, what appeared as a scientific truth at given moment, can have been so much used that it transforms deeply the perception of the reality and the way of envisaging the solutions. On this point, the current perceptions in the Sirba basin must be updated. As demonstrated by this study, the lack of water does not come from the decrease of the rain. The consequence of this perception not very just, is that the promoted solutions such as reforestation to prevent the advance of the desert at all costs, the establishment of a water access policy to allow better distribution of the scarce resource between different users, do not address the real causes of the problem. These panacea solutions to the decrease in water resources are however based on a consequence and not on a cause; what doubtless makes them ineffective. Indeed, the cause of the decrease in water resources, at least at the local level, is the increase of the temperature and the evapotranspiration and not the decrease of the precipitation. So, it is necessary to think about the fight against evaporation and evapotranspiration. Also, solutions as solid water should be thought about, underground tank construction, reduction of the exposure of the surfaces of water to the evaporation by any techniques of covering, reduction of the albedo, etc.

This study invites in a perpetual questioning of the functioning of the ecosystems and calls out on the unchanging truths often used as base of the thought on the land planning.

A space, misunderstood, misinterpreted, misjudged by a community, a society, is consequently badly used and badly lived. Well

understand an environment and update knowledge of this environment is an imperative issue for sustainable land planning.

ACKNOWLEDGEMENTS

The authors express their thanks To Global Water Initiative GWI program of IUCN and his staff, especially to Mr. Drissa Soulama, Mr. Nouhoun Sanou, Engineers at IUCN and Dr. Sawadogo Moumouni, head of the IUCN office in Burkina Faso

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Gado Djibo A, Seidou O, Karambiri H, Sittichock K, Paturel JE, Saley HM. Development and assessment of non-linear and non-stationary seasonal rainfall forecast models for the Sirba watershed, West Africa. J. Hydrol. Reg. Stud. 2015;4: 134–152.
2. Contribution of satellite imagery in the monitoring of natural resources in the east of Burkina Faso, water engineering master memory, option environment and water, International Institute for Water Engineering and the environment (2iE) in Ouagadougou. 2010;64. (French)
3. Giannini A, Biasutti M, Held IM, Sobel AH. A global perspective on African climate. Clim. Change. 2008;90:359–383.
4. RISACC, Climate change impacts on water resources of the basin Wayen Nakambé. Final report. 2010;114. (French)
5. Carbonel and Hubert, Statistical approach of aridity process in the West Africa. J. Hydrol. 1986;95:165-183. (French)
6. Hubert P, Carbonel J-P. Statistical approaches to the study of long-term rainfall series of West Africa. Trav. et Doc.; ORSTOM; 1986. (French)
7. Gouzis M, Albergel J, Carbonnel JP. Climatic deterioration in Burkina Faso: Water resource and crop production effects; Sahel-Northeast; Colloque Nordest-Sahel. Doc. ORSTOM ; n°26816 Cote BP149. 1986;16. (French)
8. Mahé G. The impacts of land-use/land-cover change and climate variability on the hydrology of the Sahel. IAHS-AISH Publication. 2006;679-684.
9. Sittichok K, Gado Djibo A, Seidou O, Saley HM, Karambiri H, Paturel J. Statistical seasonal rainfall and streamflow forecasting for the Sirba watershed, using sea surface temperature. Hydrol. Sci. J; 2014.
Available:http://dx.doi.org/10.1080/02626667.2014.944526.
10. Abraham T. The experience of induced rains in the Sahel, acts of the 9th International Symposium of Francophone specialists in impact assessment, conferences, International Francophone Secretariat for Environmental Assess-Ments, Colloques. SIFEE; 2004. (French)
11. Zoungrana TP. The hydraulic territorialisation in Burkina Faso: Models of development in the test of the territory; Cahiers du CERLESHS; N°25. 2006;409-436. (French)
12. FAO. Determination of the value of forests: Context, problems and orientations. Rome; 2000.
13. Sondo R. Impact of Wood energy on the vegetation degradation in the town of Gaoua. Geography Masters Thesis, University of Koudougou; 2014. (French)
14. Ibrahim B, Karambiri H, Polcher J, Yacouba H, Ribsttein P. Changes in rainfall regime over Burkina Faso under the climate change conditions simulated by 5 regional climate models. Clim. Dyn. 2014;42:1363–1381.
15. Dango L. Contribution to the analysis of the aridity of the Sahelian climate at the local level, the case of the downstream of Sirba basin; memory of Master's degree in engineering of the water and the environment; option: hydraulic infra-structures, International Institute of Engineering of the water and the environment (2IE) of Ouagadougou; 2013. (French)
16. Penman HL. Natural evaporation from open water, bare soil, and grass. Proc. Roy. Soc. (London, U.K.) A193 (1032): 1948, 120–145. Bibcode:1948RSPSA. 1993;120.
DOI: 10.1098/rspa.1948.0037
17. Kabdel. Aridification, studies and determinism and criteria of identification; bibliographical synthesis. 1988;88. SGN 615, BRGM, France. (French)
18. Bannayan M, Sanjani S, Alizadeh A, Lotfabadi SS, Mohamadian A. Association

between climate indices, aridity index, and rainfed crop yield in northeast of Iran. Field Crops Research. 2010;118(2):105-114.

19. Sircoulon. Variation of the debits of streams and levels of lakes in western Africa since the beginning of the XXth century. Symposium AISH, Vancouver. 1987;n°168:13-25. (French)
20. Kouassi AM, Kouamé KF, Koffi YB, Dje KB, Paturel JE, Oulare S. Analysis of climate variability and of its influences on seasonal rainfall regimes in West Africa: case of the N'zi (Bandama) watershed in Ivory Coast. Cybergeo: European Journal of Geography; 2010. (French)
21. Planton S, Déqué M, Douville H, Spagnoli B. Impact of climate warming on the hydrological cycle. Comptes Rendus Geoscience. 2005;337(1):193-202. (French)

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/13566