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The vulnerability of swamp rice production to the observed effects of rainfall and temperature variability in Ndop sub-division, Cameroon

La vulnérabilité de la production du riz aux effets de la variabilité des précipitations et des températures dans les marais de Ndop, Cameroun

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Abstract:

A vulnerability assessment of rain fed rice production to the effects of rainfall and temperature variability in Ndop sub-division in the North-West Region of Cameroon was conducted in 2015. A chronological time series data for the last 24 years on climatic variables and rice production was instrumental in four swamp rice agro-ecologies namely Bambalang, Bamesseng, Bamali and Bamunka, which are the villages of this sub-division. Utilizing a research methodology that entailed the administration of questionnaires and field observation complemented with topographical maps, aerial photos, satellite images and data from other secondary sources, the vulnerability of swamp rice production to the observed effects of rainfall and temperature in Ndop sub-division was investigated. The findings show that decreasing rainy season rainfall, unreliability in onset and duration of rainy season, inter annual fluctuations as well as increasing rainfall intensities leading to frequent floods were the main observed effects of rainfall variability affecting swamp rice production. Rice production is vulnerable to minimum temperature, extreme temperature anomalies as well as occasional droughts. The observed effects of rainfall variability had a statistically more significant effect than temperature. Farmers increase surface area under cultivation as the main form of adaptation which is less effective. The enforcement of adopting the Nerica variety with a wider tolerance range could remedy the situation but much has to be done to facilitate the adoption of the innovation. Major implications on present and potential rain fed rice production are shrinking of the growing season, floods, cold injury and heat stress, increased weeds and eventually low income and food insecurity. Based on the above findings, it is suggested that there is a need for multi-level interventions on adaptation to climate change and variability taking into account a wide range of stakeholder involvement.

Résumé:

Une évaluation de la vulnérabilité de la production du riz pluvial aux effets conjugués de la variabilité des précipitations et des températures a été réalisée en 2015 dans l'arrondissement de Ndop dans la région du Nord-Ouest du Cameroun. Une série de données chronologiques pour les 24 dernières années sur les variables climatiques et la production de riz a été expérimentée dans quatre des marais agroécologiques dont Bambalang, Bamessing, Bamalli et Bamunka qui sont des villages de cette circonscription administrative. La méthodologie de recherche qui combine l'administration de questionnaires et des observations de terrain a été complétée par l'utilisation des cartes topographiques, des photos aériennes, des images satellites et des données provenant d'autres sources secondaires. Les résultats montrent que la diminution des pluies en saison des pluies, le manque de fiabilité dans les dates du début et la durée de la saison des pluies, les fluctuations interannuelles ainsi que l'accroissement de l'intensité des pluies provoquant des inondations fréquentes ont été les principaux effets observés de la variabilité des précipitations qui affectent la production du riz inondé. En outre, cette production de riz est vulnérable aux anomalies de températures extrêmes ainsi qu'aux sécheresses occasionnelles. Toutefois, les effets observés de la variabilité des précipitations ont eu un impact statistiquement plus significatif que ceux de la température. La principale forme d'adaptation qui est la moins efficace a été l'augmentation des superficies cultivées par les agriculteurs. L'adoption de la variété Nerica avec une marge de tolérance plus large pourrait remédier à la situation. Cependant, la sensibilisation est nécessaire pour faciliter l'adoption de cette innovation. Toutefois, subsistent des implications majeures sur la production actuelle et potentielle du riz pluvial, notamment : la réduction du cycle saisonnier de croissance, les inondations, les préjudices liés aux incursions du froid et au stress thermique, l'augmentation des mauvaises herbes et, éventuellement, les faibles revenus et l'insécurité alimentaire. Sur la base de ce qui précède, des interventions multiscalaires sont nécessaires pour l'adaptation des parties prenantes au changement et à la variabilité climatiques.

Keywords / Mots clés

Climate variability, Vulnerability, Regression analysis; Swamp rice production; Ndop sub-division
Variabilité climatique, Vulnérabilité, Analyse de la régression, Production du riz inondé, Ndop sub-division

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INTRODUCTION

Climate Change has many facets including changes in long term trends in temperature and rainfall regimes as well as increasing year to year variability and a greater prevalence of extreme events. These inter monthly and annual variability has become a major concern worldwide. Globally, mean temperatures over the last 30 years showed a pronounced upward trend and were above the long-term average of the past 100 years (Tsalefac and Amougou, 2008). Due to increases in temperature, rainfall has already become variable and unpredictable and the strength of climate related extreme events such as droughts, floods, heat waves and cyclones are anticipated to increase in the future (FAO 2006, IPCC 2007, 2014). Rainfall has been very much unreliable in terms of onset, duration and termination due to the present trend of climate change. Major symptoms of such variability include disruption of normal climate patterns over large areas, increasing incidence of drought and high temperatures, heavy flooding and increasing levels of salt stress both in inland and coastal areas.

Agriculture is determined by chief climatic factors of rainfall and temperature and variations in any of the above factors will consequently affect crop production (Manneh et al., 2007). Climate variability and crop yields are the concern of most stakeholders today. Therefore the main climatic conditions which support the growth and development of plants are temperatures and rainfall. Long term variations of any or both of these conditions, either positively or negatively, will affect the environment and consequently the proper growth, development and production of such a plant.

Weather and climate have a direct influence on cropping systems and plant yield. Thus, weather fluctuations and climate variability play a significant role in crop growth and yield. Occurrence of abnormal weather episodes during the growing season or during critical development stages may hamper growth processes resulting in yield reduction. This makes climate variability a threat to food production leading to serious social and economic implications (Geng and Cady, 1991; Hossain, 1997). However, a clear understanding of the vulnerability of food crops as well as the agronomic impacts of climate variability enable one to implement adaptive strategies to mitigate its negative effects.

Studies carried out by Tani (1978), De Datta (1981), Wanki (1985), Parry (1990), Rosenzweig and Parry (1994), Parry et al. (1999), Peng et al (2004), Sarker (2012), IPCC (2007, 2014) observed that high temperature (heat) stress and cold injury induce many biochemical, molecular and physiological changes and responses in turn influence many cellular and whole plant processes that affect crop yield and quality, especially in the tropics. Yoshida (1981), Katz and Brown (1992), Lansigan et al., (2000), Ekpoh, (2002), Ngakfumbe, (2004), Tabi et al (2010), observed that, decreasing rainfall amount, changing rainfall pattern, early or late onset of rains, erratic rainfall, frequent storms, drought and short rainy season, are leading to reduce water availability below certain threshold values causing the drying of swamps and consequently exposing rice farming to greater vulnerability in semi-arid regions. Climate change represents an additional pressure on the world's food supply system and is expected to increase yields in some areas at higher latitudes and decrease yields at lower latitudes (IPCC 2007, 2014). According to Anderson et al. (1987), Rosenzweig (2008), Molua (2009), Hassan and Nhemachena (2008) the most common adaptation strategies in agriculture include changing crop varieties, irrigation, planting trees, crop and livestock diversification, soil conservation, early and late planting, increasing plant spacing, use of clay soil, and adjusting the level and timing of applying fertilizer. The main barriers to effective adaptation include lack of information, lack of access to credit and land, and water shortages (Yesuf et al., 2009; Deressa et al., 2009).

The effects of climate change and variability have been studied in most cases on a meso and micro scale but considerable gaps still exist at local scales. This is the case of Ndop sub-division (NSD) which is famous for its rain-fed and partly irrigated swamp rice production through red fed streams. The varieties under cultivation called Taina, Variety 14(V14) and Tox which are expected to yield 4, 5, and 6 tons respectively but these thresholds have never been attained due to temperature and rainfall fluctuations. The main research problem here relates to the significant changes in these elements which either individually or combined greatly affect rice yields and consequently production which constitutes 60% of the economy of this subdivision. This paper therefore investigates the observed effects of current changes in rainfall and temperature patterns in this sub-division and how they expose rice production in the study area to vulnerable conditions.

MATERIALS AND METHODS

The methodology that has been adapted entailed classical and empirical approaches. Data was collected from secondary sources via main Libraries of the University of Yaounde 1, the World Bank, Ministries of Agriculture and Rural Development. Numerical data on Temperature, rainfall, number of rice farmers, surface areas, rice production in tons were collected from UNVDA (Upper Nun Valley Development Authority). Topographic sheets of Bafoussam 3c (Foumban Dchang) at the scales 1:50 000 1:200 000), Aerial photos and LANDSAT image of 2010) have been utilized for location and mapping of specifics sites.

Field observation was enhanced by the use of Structured interviews administered to 7% of resource persons working at the UNVDA. A stratified 11.64% of farmers who have cultivated for at least 25 years were selected at random from the four villages so as to provide reliable information on the past and present situation. The stratified random distribution was administered as shown on table 1.

Agro-ecological zones	Total population of rice farmers	Sample population (≥ 25 years of farming)	Percentage sample
Village 1. Bamunka	1876	50	2.67%
Village 2. Bamali	304	10	3.31%
Village 3. Bamesseng	307	10	3.25%
Village 4. Bambalang	850	20	2.41%
Total	3337	90	11.64%

Table 1: Spatial distribution of questionnaires in the study area
Source: Field work 2015

Statistical Analysis System (SAS) was used for analysis of variance (ANOVA) of the average seasonal precipitations of the whole region and the station located in the study area. This process was employed to validate the use of divisional climatic data at a sub-divisional level. Five-year running averages were used to normalize the erratic nature of inter-annual averages. Coefficient of variation was employed so as to determine the reliability nature of the weather variables under study. The coefficient of variation is a statistical tool which determines the reliability index of a parameter.

Coefficient of variation (CV) = (standard deviation: Mean) × 100

Student's t-test was used to establish any difference or similarities in the two data sets of temperature, rainfall and rice production.

Simple regression analysis for divisional rainfall data was performed by MS Excel using the model below: Y (j) = ak + c ………… (1) Where: Y (j) = Physical factor (rainfall, temperature) a = Gradients (slopes) of the regression equation k = Number of growing seasons (years) from 1990/91 to 2013/14 due to data availability; c = Regression constant

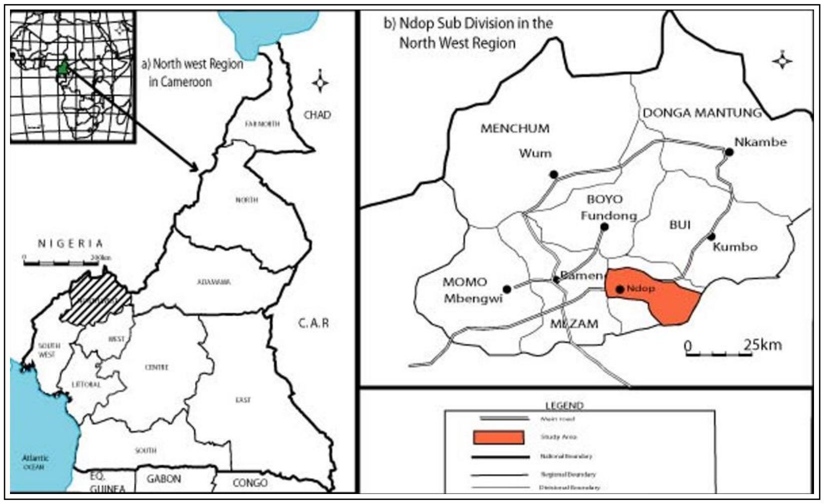
To determine if Ndop subdivision had been affected by present trend of temperature changes, the aridity index has been calculated. The De Martonne (1923) formula has been used to calculate the aridity index. The formulae is; I= P/T+10 where; I= Aridity index P= Average annual Rainfall T=Average annual Temperature. As I values increases, the tendency is towards hyper arid or absolutely desert areas and vice versa. The results were then compared with inter-annual production to determine vulnerability.

The XY scatter plot was produced with both regression line and regression equations established. The R–square (R2) values were recorded for each analysis for the purpose of determining the significance of the trends.

The cartographic part of this work was realized by the use of Computer Assisted Drawing and GIS programs such as Adobe Illustrator 9.0 and ArcGIS. Data analyses were then realized by the use of the S.P.S.S (Statistical Package for Social Science) and EXCEL. Data on the Findings of the research has been presented in the form of tables, figures, Graphs and synoptic Charts

PHYSICAL BACKGROUND OF THE STUDY

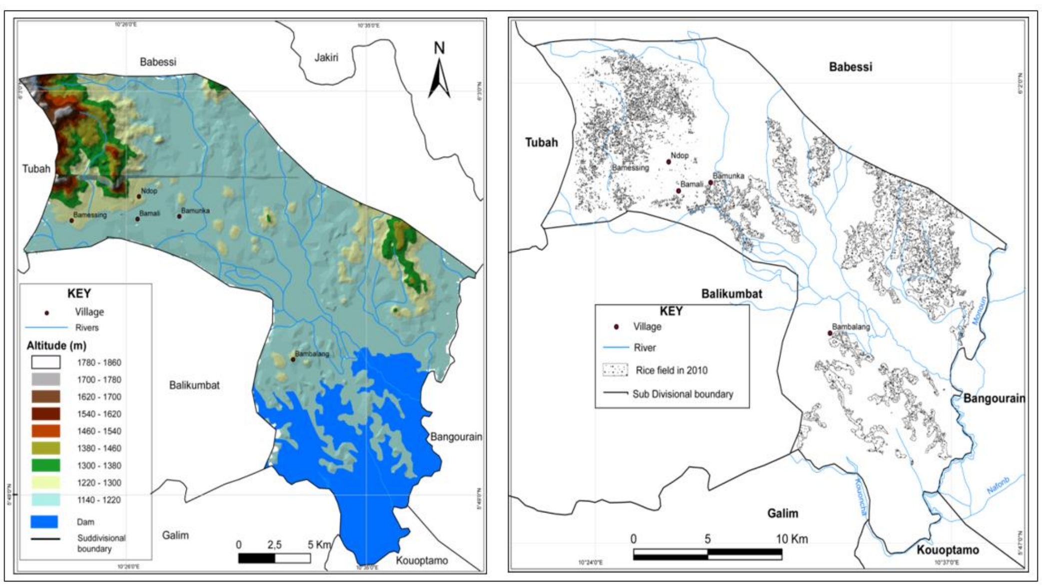
Ndop Subdivision (figure 1) is located between latitude 5º 37' N to 6º 14' N of the equator and between longitudes 10º 23' E to 10º 33' E of the Greenwich Meridian. It is found in the North West Region of Cameroon, precisely in Ngoketunjia Division.



Source: Cameroon Geographical Review and National Institute of Cartography

Figure 1: Location of study area

This subdivision is made up of 4 rice agro-ecological zones which are Bamunka, Bamali, Bambalang and Bamesseng. This area has an average temperature of about 26ºc with average maximum daily temperature of 27.22ºc and minimum average of between 11ºc and 14ºc which fluctuates rapidly than the maximum. Inter annual average rainfall varies between 1524mm and 1770mm and the rainy season lasts for 7-8months. The gently sloping nature of the topography (figure 2a) lends itself into the predominance of extensive wetlands which have favored intensive rice cultivation. The north and south combination of hills and mountain chains are separated by the Ndop flood plain which is studded by numerous marshes or swamps into which a host of tributaries unite to form the main irrigation river into the rice fields called the noun river downstream (Lambi, 1999).



Source: Atlas map of Cameroon and Field work

Figure 2a: Relief and drainage map of Ndop Sub Division.
Figure 2b: Rice cultivated areas of Ndop Sub Division by 2014

Besides the climate, relief and drainage, the presence of trachytes, rhyolites common in this area gives rise to ephemeral streams due to their low porosity and permeability. Weathering of these rocks including the volcanic and granitic rocks on the lower altitudes produces basalts and granitic sandy soils. Consequently, farming tends to drift away from hilly areas to areas of sediment accumulation at the plains thereby favoring intensive rice cultivation. According to Lambi, the alluvial (A-soils) on the flood plain have been extensively used for wetland rice cultivation. These soils are generally fertile due to annual increments of alluvial deposits from the surrounding highlands. Besides clay and alluvial deposits in the wetlands, ferrite and hydromorphic soils are also found in the wetlands. These soils are poorly drained because of their reduced porosity and permeability, hence giving rise to swamps and wetlands. These physical conditions have created an enabling environment for swamp rice production in NSD. The population estimated at 100 000 inhabitants (2010 national census board) as well as the land use dynamics has enabled the availability of cheap and abundant labour force required at the different stages of plant growth. The existence of wetlands, plains, and highlands has greatly influenced land use patterns of agriculture and settlement of this subdivision of which rice cultivation is the dominant economic activity (figure 2b).

RESULTS AND DISCUSSIONS

OBSERVED EFFECTS OF CLIMATE CHANGE AND CLIMATE VARIABILITY IN NDOP SUB-DIVISION

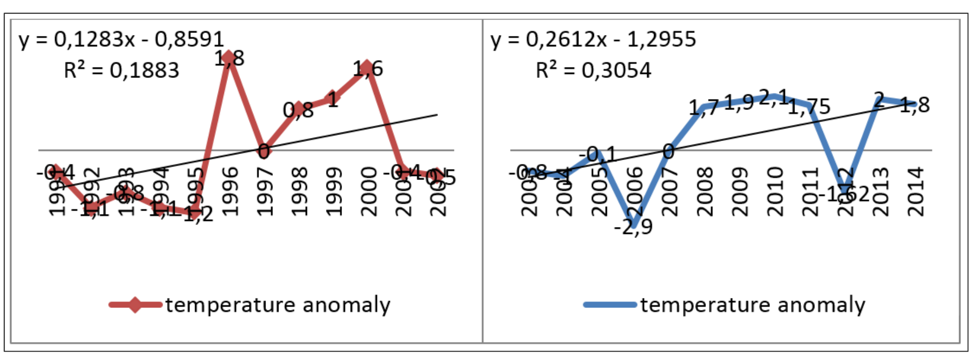
The inter-annual and five-year observed pattern of rainfall variability shows a steady fluctuation in rainfall with a gradient of 0.54 and a negligible r2 value of 0.01 and a relatively alternating one sub period of excess (first sub decade) and four sub decades of deficient water supplies (last 4 sub decades). The negligible increasing trend is a reflection of the average seasonal changes with a slight decrease in rainy season rainfall and a sharp increase in dry season rainfall as seen on the table 2.

Decade	Rainy season (mm)	Dry season(mm)
1991-2002	232.3	5.9
2001-2014	212.9	18.6

Source: Field work 2015

Table 2: Seasonal changes in rainfall amount

Contrary to rainfall, temperature has been experiencing a rapidly increasing inter-annual trend with a gradient of 0.29 and r2 of 0.74 with a progressive increasing 5-year moving average trend characterized by increasing both rainy season and dry season average temperatures. A wide disparity was observed between maximum and minimum temperatures with a relatively rapidly decreasing mean monthly minimum temperature trend with a negative gradient of -0.186 as opposed to a gradual but progressive mean monthly maximum temperature trend with a gradient of 0.023. Extreme positive and negative temperature anomalies were observed as indicated on Figure 3.



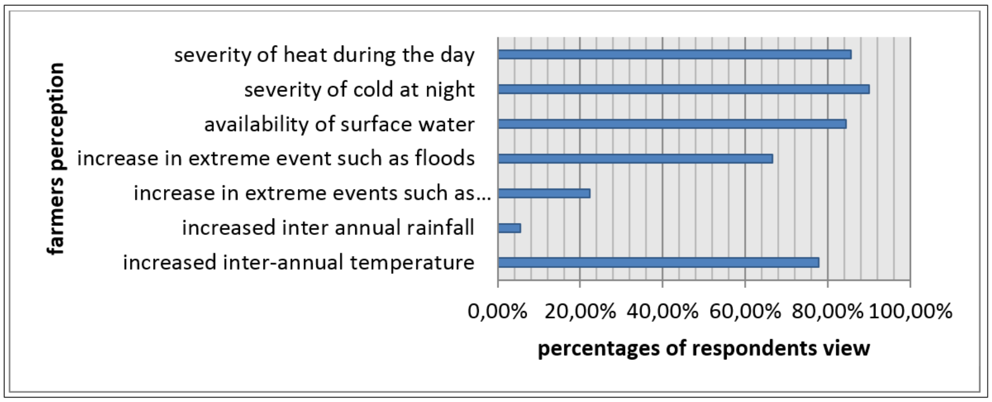
Source: Field work 2015

Figure 3: Temperature anomalies based on first period and second period averages

Three extreme anomalies were observed based on the first and last 12-year averages as observed on figure 3 above. These entailed two positive extreme anomalies in the first period and one negative extreme anomaly in the second period. In terms of reliability, temperature was more reliable during the study period than rainfall with high coefficient of variation averages which are 10.65% 18.22% 19.74% 16.44% 18.45% than temperature which are 1.22% 2.46% 1.13% 6.51% 7.2% relatively. However in absolute terms both parameters were observed to be reliable in terms of their 5-year running averages.

Result from the De Martonne aridity index presents Ndop Subdivision as a generally humid area. I values of I≥55 was observed for most of the years throughout the study period and relatively few years of semi-humid conditions as well as hyper humid conditions.

Climate change is perceived differently at different levels of conceptualization. Through key informant interviews and responses to questionnaires, it was revealed that there is varied understanding on climate change and variability depending on the level of education, livelihood activity, location, and age. The local understanding on climate was that climate is continuously changing and it is getting worse over time. Bad years are becoming more frequent than before, resulting in poor performance in agriculture and consequently food shortages in the area. Farmers involved in rice cultivation for at least 25 years acknowledged an increase in meteorological and hydrological droughts, flash floods, cold stress at night as well as heat stress during the day, irregularity in the onset, duration and termination of rains as observed on figure 4.



Source: Field work 2015

Figure 4: Perception of rice farmers on the effects of climate variability and change

Inconsistent rainfall and temperature are reducing rice production in the Ndop plain. The results further show that experienced farmers older than 40 years perceived temperature to be hotter relative to old days especially during the day. Through Focus group interviews with farmers and workers at the extension service (UNVDA), it was realized that much of the changes in temperature had occurred during the last 14 years. Stakeholders' perception on rainfall trends was more consistent as 100% observed unreliability in terms of onset, duration and termination and not necessarily the inter-annual rainfall amount per se.

IMPLICATIONS OF THE OBSERVED EFFECTS OF CLIMATE CHANGE AND VARIABILITY ON RICE PRODUCTION IN NDOP SUB-DIVISION

A close relationship in the inter annual and 5-year running mean curves between rainfall and rice production shows that rice production is highly influenced by rainfall. This relationship is weak in terms of similarities in the curves of temperature and rice production except for the years of extreme temperature anomalies (1996 and 2006) as seen in Figures 5a and 5b.

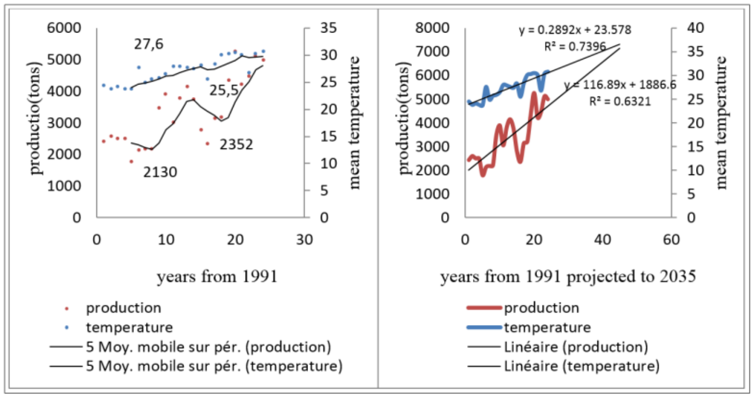


Figure 5a: Regression lines and curves between mean temperature and rice production

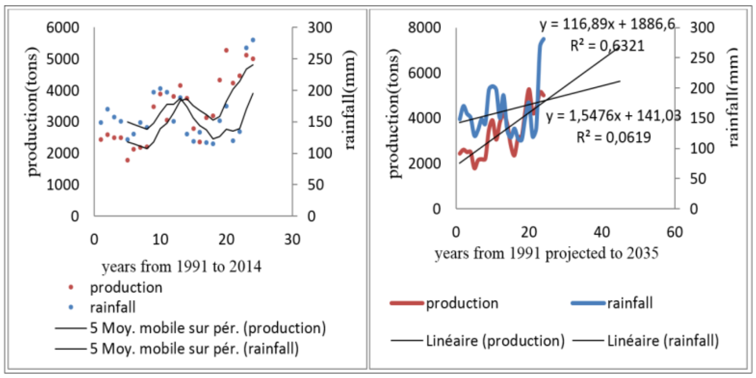


Figure 5b: Regression lines and curves between mean rainfall and rice production

From regression curves above, years with above 150mm of rainfall on average corresponds to years of above 3000 tons of production and vice versa. R2 values of inter-annual rainfall trend indicate a negligible increasing rate indicating a future shortage in water supply for rice cultivation especially during the rainy season. R2 values for temperature indicates a rapidly increasing trend which will expose the rice plants to more heat stress affecting output.

A close relationship can be observed between the aridity indices and rice production. The years with high I values (I ≥55) have the highest rice production values while the years with lower aridity indices have lower production values relatively speaking.

Year (for each sub decade)	Aridity Index(I)	Production in tones	Year(for each sub decade)	Aridity Index(I)	Production in tones
1992	60.4	2598	1995	43.3	1782
2000	66.7	3893	1996	42.7	2130
2001, 2003	62.3, 60	3045, 4152	2005	37.2	2787
2010	51.9	5268	2007, 2008	36.4, 34.9	3141, 3199

Source: Field work 2015

Table 3: High and low I values versus Production

Table 3 presents a situation where the highest I values for each sub decade directly correspond to years of highest rice production except for the year 2001. The same situation is reflected in the years with the lowest I values except for the year 2007.

This indicates that rice production is vulnerable to arid conditions and vice versa. Therefore, faced with a future of increasing high air temperatures, rice production will be threatened in this subdivision due to arid conditions especially as rainfall becomes more unreliable.

It was also observed that variation in the amount of rainfall in the study area before 1st May and after the 31st of April influenced the initiation of the rice growing season which consequently affected production. Rice production starts as soon as the cumulative amount of rainfall for the last 30 days after April 1st reaches 200mm (Yoshida, 1977). The situation is presented on the Table 4.

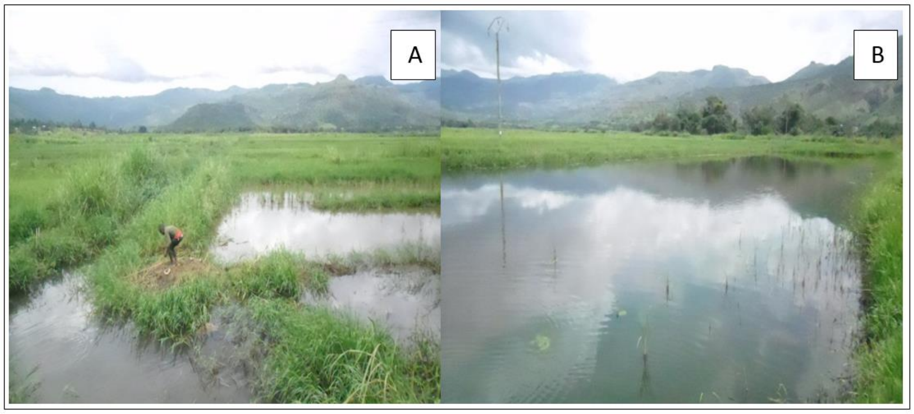
Year	Date of onset of rainfall	no of rainy days after April 1st	Total amount by 1st May	Observation
2006	22nd January	21	76.2	less water, high vulnerability
2007	14th February	18	263.95	Normal water, low vulnerability
2008	5th March	15	132.3	less water, high vulnerability
2009	3rd March	08	257.6	normal water, high vulnerability
2010	4th February	17	108.5	Less water, high vulnerability
2011	10th February	07	84.4	Less water, high vulnerability
2012	18th February	12	124.6	Less water, high vulnerability
2013	9th March	23	315.5	Much water, high vulnerability
2014	12th March	18	142	Less water, high vulnerability

Table 4: Reaction of rice plant to different levels of water availability

From the analysis on the table above, most years with high number of rainy days after April 1st had lower amounts of rainfall before 1st May. Years which had lower amounts of rainfall before 1st May of less than 200mm exposed production to vulnerable conditions as there was insufficient water on the rice fields. Farmers in some cases often varied their planting dates as a means of adaptation.

CV values of more than 17% indicate fairly unreliable rainfall which affects rice production while CV values of less than 15% do not affect production as observed in the circular changes in these variables. Relatively years with above 17% of CV values correspond to years with below 3000 tons of production and less than 4 tons per hectare while years with less than 17% CV experienced a reverse trend. Production is therefore vulnerable to fairly unreliable rainfall.

Based on calculated t-value for rainfall, temperature and rice production with a degree of freedom of 46, significant at a 0.001 level indicate a 99.9% chance that the response variable is highly dependent on the operational variable. Inter-annual changes in both parameters often induces stress conditions to the semi-aquatic plant as observed on the photos a,b,c and d. The observed effects of the irregularity in the onset of rainfall and the shortening of the rainy season with increasing rainfall intensities often leads to inundation of more than half of swamp rice plants during the mid-season stage (photo 1a and b).



Source: Field work 2015

Photo A: Effect of ¾ submergence under flood water
Photo B: Effect of uprooting by flood water

This period of spikelet productivity and flowering which requires just ¼ inundations for all the varieties under cultivation (Taina, Tox and Variety 14) is the most vulnerable period to water stress as reported by all rice cultivars at downstream area of River Noun (Bamunka and Bambalang agro-ecological zones). Coupled with the poor drainage (photo b) and irrigation techniques, during occasional periods of heavy rain storms, River Noun and its main tributaries often overflow their banks there by uprooting the rice plants or tolerating weeds (photo 1c) which compete and dominate the swamps. Eventually the rice population is reduced (photo 1d), consequently affecting production. Occasional droughts which often lead to the drying of the rice swamps as well as the rain fed streams that irrigate the swamps dehydrate the plants, thereby reducing production.

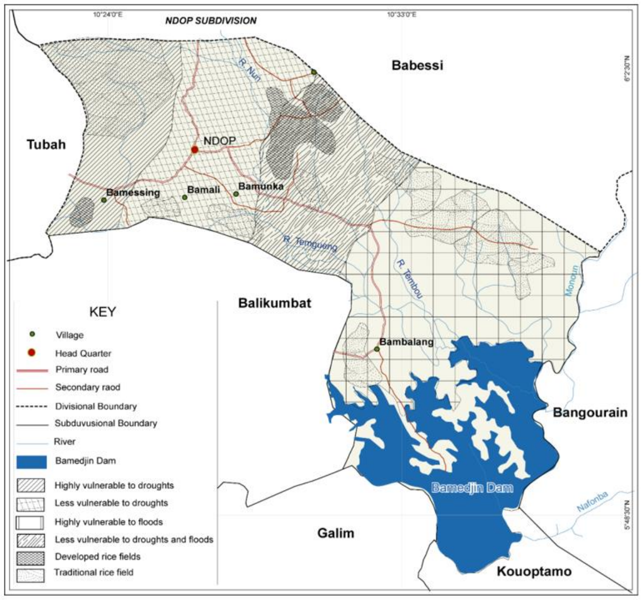
Source: Field work 2015

Photo C: Proliferation of weeds
Photo D: After effects of flooding

Rice production in this subdivision is also affected by the decreasing mean night temperatures as well as the increasing mean day temperatures because the plants often grow beyond their mean night and above their mean day optimum temperatures. Cold injury as well as heat stress affects the proper growth and consequently the yields, especially in years of extreme anomalies such as the 1996, 2006, 2007 and 2009 situations. The most vulnerable developmental stages to cold injury is the germination, seedling emergence and flowering stages as observed in 2006 when the plants in June, July and September grew beyond their minimum tolerance limits. This corresponds with Satake and Yoshida (1978), who explained that even a slight change in temperature during a critical stage (e.g. flowering) may already result in significant reduction in crop yield.

According to results from the analysis of questionnaires on the dominant impact, 44.4% of farmers interviewed observed that it is low crop yield; 22.2% observed stunted growth of crops; 16.7%

recognized easy spread of pest and diseases attack on crops; 11.1% observed that it was the drying of seedling after germination and 5.6% observed that it was due to the ineffectiveness of agricultural chemicals caused by delay in rainfall. However whatever the magnitude the above factors are viewed as products of climate variability on swamp rice production in this subdivision. It was also observed that the climatic risk factor exposing production to vulnerable conditions varied with the village. The risk factor and zone is presented on figure 6.



Source: Atlas map of Cameroon and Fieldwork

Figure 6: Vulnerability map of rice production to droughts and floods

The vulnerability map presents Bambalang rice agro-ecology to be the most vulnerable to floods due to its downstream location while Bamesseng rice agro-ecology was observed to be the most vulnerable to droughts due to its upstream location and the presence of ephemeral rain fed irrigation streams which are unable to supply the rice fields in times of water need.

As a means of adaptation, farmers have often increased their surface area under cultivation but this has not increased yields per hectare as all the varieties under cultivation have never attained the expected yield levels of 5 (Taina variety) and 6 (Tox) tons. Less than 5% of the entire rice growing population has adopted the Nerica specie introduced in 2010 by IRAD which has a wider tolerance range to floods and droughts. Besides these, farmers have often adapted their farms to the effects of extreme conditions by creating local conservation pools along their banks to regulate the in and out flow of water in their farms. The extension service (UNVDA) in charge of promoting rice farming in this sub-region has on its part build local drainage and irrigation channels to regulate water supply in and out of the various rice plots. This is to reduce vulnerability to floods and droughts but this method has however been less effective because bank breakage (photo 1b) often occurs during heavy rainfall.

Much has therefore been done at the level of spontaneous adaptation methods which is only a coping strategy but little has been done at the level of planned adaptation. The main barriers to effective adaptation as reported by farmers and other resource persons on the field include, lack of climatic risk information, insufficient capital, education and absence of adequate and efficient adaptation strategies.

CONCLUSION AND RECOMMENDATIONS

The study concludes that stakeholders including farmers at village level have revealed that climate is continuously changing and it is getting worse over time. There is a concern that rainfall amount has not necessarily changed in terms of annual amount but there is an observed gradual shift in rainy season amount to dry season and it has become more unreliable in terms of its onset, duration, intensity and termination while temperatures have increased. Bad years are becoming more frequent than before, resulting in rice food shortages in the area.

While this could also be due to other factors, trends of rainfall, temperature and dry spells, cold injuries and floods provide evidence that rain fed agriculture in the study area is vulnerable to the impact of climate variability. Rainfall has generally been more unreliable over the last 24 seasons, while the difference in both minimum and maximum temperature has become wider. This was coupled with extreme anomalous behavior of inter-seasonal mean temperatures. The nature of dry spells during this period is very important as it affects most crops at their crucial period of growth when adequate moisture is required and it also leads to the drying up of irrigation streams. Common in this area was the frequent occurrence of flash floods which often uprooted crops, favored the growth of the most aggressive weeds that compete and kill the plants, affect the tiller number and spikelet production. These results may constitute some useful information required by different levels of actors in development, particularly in reducing vulnerability of rain fed cultivators in the Savanna regions of Cameroon.

The study therefore recommends for development of appropriate strategies for reducing vulnerability of rain fed agriculture by helping farmers to use their local knowledge in combination with introduced innovations to enhance local adaptations to climate change and variability. The incidence of pests and diseases may be hastened by the fluctuations in weather variables, such as temperature and rainfall patterns. Scientists and farmers must join efforts to further understand crop–climate relationships to help them formulate viable, location-specific production technologies that will address critical issues such as the effects of climate variability. Such strategies could vary from crop level to farm level and finally to farmer's level of adaptation. Introducing varieties with wider tolerance ranges such as the NERICA (New Rice for Africa) variety introduced in 2010 at crop level is one strategy to reduce vulnerability. However, farmers need to be equipped with the necessary abilities so as to adopt and implement this innovation. Implementing and improving rice crop water management techniques such as, varying planting dates, educating farmers on climate change information amongst others, are part of the sustainable strategies that can enable increased rice production in this subdivision and permit the attainment of the expected yield levels.

An enabling environment should be created to allow for smooth response to other crops as an adaptation to climate change and variability and sustaining adequate food security. Stakeholders involvement and joint action among researchers, extension officers, farmers and policy makers would likely help define and implement this roadmap.

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