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RESEARCH ARTICLE
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Cost-effectiveness of agriculture risk management strategies for resilience to climate shocks in Niger State, Nigeria

Rentabilidad de las estrategias de gestión de riesgos agrícolas para la resiliencia a los choques climáticos en el estado de Níger, Nigeria

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Abstract

The ability of a system, community or society exposed to hazards to resist, absorb, to accommodate and recover from the effects of a hazard in a timely and efficient manner is termed resilience. In this study we used a recent cross-sectional survey data of 293 farming households in Niger State, Nigeria to examine the cost effectiveness of risk management strategies for resilience to climate shocks. Benefit-cost analysis of mitigation strategies was examined where benefit-cost ratio (BCR), and net present value (NPV) were used as decision rules. The mitigation strategies mostly used were drought tolerant crops (62.8 %), crop diversification (60.8 %), buffer stock (54.6 %) and dry season farming (41.3 %). The result showed that about 52 % of the sampled households were food secure while 48 % of them were food insecure. The result showed that dry season rice farming had the highest net benefit (NB) and NPV ($ 199.98) while rain fed maize ($ 35.01) and rice had the least NPV; the result showed the NPV for drought tolerant crops- cassava ($ 170.25), millets ($ 101.58) and sorghum ($ 96.43). The study recommends that households should take up dry season rice farming and grow drought tolerant crops such as cassava, millets and sorghum. Governments should invest in and research and breeding of drought tolerant crops in order to improve food security and household resilience.

Keywords: *benefit-cost, risk management, resilience, food security, irrigation farming.*

Resumen

La capacidad de un sistema, comunidad o sociedad expuesta a peligros para resistir, absorber, adaptarse y recuperarse de los efectos de un peligro de manera oportuna y eficiente se denomina resiliencia. En este estudio, utilizamos datos de una encuesta transversal reciente de 293 hogares agrícolas en el estado de Níger, Nigeria, para examinar la rentabilidad de las estrategias de gestión de riesgos para la resiliencia a los choques climáticos. Se examinó el análisis de beneficio-costo de las estrategias de mitigación donde se utilizaron como reglas de decisión la relación costo-beneficio (BCR) y el valor actual neto (VAN). Las estrategias de mitigación más utilizadas fueron los cultivos tolerantes a la sequía (62.8 %), la diversificación de cultivos (60.8 %),

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las existencias reguladoras (54.6 %) y la agricultura de estación seca (41.3 %). El resultado mostró que alrededor del 52 % de los hogares muestreados tenían seguridad alimentaria, mientras que el 48 % de ellos tenían inseguridad alimentaria. El resultado mostró que el cultivo de arroz de estación seca tuvo el mayor beneficio neto (BN) y VPN ($ 199.98) mientras que el maíz de secano ($ 35.01) y el arroz 0 tuvieron el menor VPN; el resultado mostró el VPN para cultivos tolerantes a la sequía: yuca ($ 170.25), mijo ($ 101.58) y sorgo ($ 96.43). El estudio recomienda que los hogares se dediquen al cultivo de arroz en la estación seca y cultiven cultivos tolerantes a la sequía, como la yuca, el mijo y el sorgo. Los gobiernos deberían invertir, investigar y mejorar cultivos tolerantes a la sequía para mejorar la seguridad alimentaria y la resiliencia de los hogares.

Palabras clave: *beneficio-costo, gestión de riesgos, resiliencia, seguridad alimentaria, agricultura de riego.*

Introduction

Agriculture is facing several risks in Nigeria like any other sub-Saharan African countries which occur at different rate. An increased agricultural production in Nigeria is recognized as an important factor for growth in the economic progress of the country and food and nutrition security for the rapidly increasing population (Akanbi et al., 2022). Risk management challenges in agriculture are very many, most especially in Nigeria where agricultural systems are becoming more sensitive to risks that are already known to agriculture such political environment, demography and economic changes, and climatic factors and the emerging ones like price volatility, supply chains, and zoonoses (Obiri et al., 2017). The known livestock and crops varieties are already exposed to climate changes that impact their biochemical properties and physiology resulting to bad productivity. There is a strong inverse correlation between feed intake of poultry, pigs and cow and heat stress as reported in studies (Baiyeri & Aba, 2017). Existing cultivars of crop and animals can no longer be resilient as they were before the era of climate variability.

Drought is one of the anomalies that have plagued the northern part of Nigeria since the beginning of the 20th century. It is the inability of rainfall to meet the evapotranspiration demands of crops resulting in general water stress and crop failures (Abubakar & Yamusa, 2013). They suggested that the probability of drought at the on-set and towards the end of the rainy season is usually very high in Northern Nigeria. Dry spells at the beginning of the season usually result in multiple plantings and low or no yields leading to low food security index. In the same vein, drought that occur at the end of season could bring about water stress at critical periods of need, especially during the reproductive stage of most crops and result in crop failures and shrinking of yields (Abubakar & Yamusa, 2013).

Typically, floods are outcome of extreme weather events such as precipitation e.g. prolongs rainfall and melting snow from snowfall, which are exacerbated by the geographical location and human activities of a place. Areas liable to flooding are low-lying areas, but the southern parts of Nigeria are more vulnerable due to the double maxima rainfall experienced for a prolonged period, usually between March-October and as early as February-November in some southern States like Cross River and Rivers States (Atu & Okon, 2018). Flood over the years has caused severe damage to property, infrastructure, crops and deaths across the country, and has been considered as a source of increased risks to disease and hunger, damage to property, loss of life, contamination, and spoiling of agricultural land (Umoh, 2008).

In Nigeria farmers are using climate-resilient adaptation measures. The major agricultural ecosystems and the broad adaptation areas are: crop farming (improved soil and land management, crop-specific innovation, water management practices, climate information services and education, access to finance, and off-farm diversification), livestock farming (improved livestock management systems, improved breeding strategies, sustainable health improvement, proper feed formulation early maturing and heat-resistant bird varieties), and fish farming (water harvesting measures, organic material, quick-maturing varieties) (Onyeneke et al., 2019).

Drought as a recurring event causes widespread yield declining as well as crop failure in some occasion, in Nigeria agriculture. Adapting to such event is very critical to ensure national food security and economic growth. One main adaptation technique is the development of drought tolerant crop varieties (Lunduka et al., 2019). A drought tolerant crop variety is a variety that has ability to produce almost 30 % of its probable yield (1 $t.ha^{-1}$ to 3 $t.ha^{-1}$) when suffering insufficient water supply for six weeks before or during flowering stage and grain formation (Magorokosho et al., 2009). In controlled experimental study, drought tolerant crops are high yielding more than several commercial hybrid varieties (International Maize and Wheat Improvement Center [CIMMYT], 2013).

Moreover, as a matter of policy knowing the cost efficiency of climate-coping strategies before applying them is very important. Understanding the cost associated with climate change adaptation interventions in agriculture is important for mobilizing institutional support and providing timely resources to improve resilience and adaptive capacities (Sova et al., 2012). Households, communities and government agencies will need to enact adaptive initiatives in order to cope with expected and unexpected climate change effects. Doing so will bear a cost. Developing countries that are already inundated with development deficits often lack the ability to meet the additional costs of adapting to climate change (Stern, 2006). Benefit-cost analysis aims to compare what would happen in the absence of a project (also called a baseline) with what happens after the project has been implemented (the project outcome). The costs of the project are weighed against the benefits that have accrued during this period of project implementation (Buckley & Peterson, 2015).

Smallholder farmers in Nigeria are facing the challenge of low agricultural productivity due to several factors including climate change. Thus majority of rural households in Nigeria are engaged in crop and livestock production as their main source of livelihood, they are making efforts to sustain their productions and improve their welfare. Most times, the benefits of the objectives of self-sufficiency and the results of farmers' efforts in the production of livestock and crop products are eroded by natural events such as floods, drought and pest infestation as well as economic failure. In spite of applying different various adaptation strategies many of the farming households are still living in suffering. The issues might be that, these farmers are not using economic strategies or they are not using these strategies the right way. The high poverty among farmers may imply that cost constraints would severely limit climate adaptation, and hence, the benefits from climate adaptation (Buckley & Peterson, 2015).

Although there are empirical studies on climate change adaptation strategies among farmers in Nigeria, few studies have conducted BCA of climate change adaptation strategies and none has conducted studies on the adoptions of drought tolerant crops and dry season irrigation farming in Nigeria. Many of the available studies have analyzed the benefit cost of climate change adaptation strategies on agricultural production and have shown the efficient strategies to farming households, none of the studies delved into the drought tolerant crops and dry season irrigation farming as coping strategies applied by farming households. Such studies include Alves (2015) analyses benefit-cost of climate change adaptation: the use of participatory methodologies. Henri-Ukoha (2020) assesses the cost-benefits of climate change adaptation strategies of cassava-based farmers in southern Nigeria. Adzawla et al. (2020) presents the benefit-cost analysis of on-farm climate change adaptation strategies in Ghana. Considering the economic implications of climate adaptation, there is a need to understand the costs and benefits of climate adaptation strategies; it is also important to understand the welfare benefits of these adaptation strategies. This would help farming households to properly identify and utilize the effective strategies and influence policy formulation and funding of adaptation strategies. Generally, studies on the cost-benefits of climate change adaptation strategies and their welfare impacts are very scarce. These studies are lacking in Nigeria, and hence there is need for this study, as this would help farming households to know the income benefits of the major adaptation strategies.

The main objective of this paper is to examine the cost effectiveness of ex-ante (i.e. action taken before a negative event to prevent the effects of that event) risk management strategies for resilience to climate shocks in Niger State, Nigeria. The specific objectives are to: (i) identify the risk management strategies employed by farming households; and (ii) examine the benefit-cost analysis of dry season irrigated farming and drought tolerant crops in the study area. We used survey data collected in 2020 from 30 villages in Niger State to examine the cost effectiveness of climate shock mitigation strategies. This present study fills the gap of previous studies by focusing on the determining factors of adaptation strategies on household in Nigeria. The result of this study is useful for policy formulation by government at all levels. It will serve also as a reference material to researchers and students alike.

Materials and Methods

Study Area

Niger State lies on latitude 8° to 11°30' North and Longitude 3°30' to 07°40' East. The State is bordered to the north by Zamfara State, west by Kebbi State, south by Kogi State, south west by Kwara State, north-east by Kaduna State and south east by Federal Capital Territory. The state also has an international boundary with the Republic of Benin along Agwara and Borgu LGAs to the North West. The State covers a land area of 76 469.90 square Kilometres, which is about 10 % of the total land area of Nigeria out of which about 85 % is arable. The 2006 population and housing census put the State's population at 3 950 249 (Niger State Bureau of Statistic [NSBS], 2012). The population projection was 5 556 200 at a growth rate of 3.5 % in 2019 (City Population, 2020). Niger State shares in all three dams of the Niger Dams Project, including one at Shiroro Gorge on the Kaduna River and one at Jebba in Kwara State, the reservoir of which lies partly in Niger State. When excess water is from these dams and reservoir during the raining season nearby villages and farms are usually flooded. It has a large hectare of inland water and vast arable land, majority of the population are farmers. Niger State experiences distinct dry and wet seasons with annual rain fall varying from 1 100 mm in the southern parts to 1 600 mm in the northern parts. The maximum temperature (usually not more than 34 °C) is recorded between March and June, while the minimum is usually between December and January. The rainy seasons last for about 120 days in the northern parts to about 150 days in the southern parts of the state. Generally, the fertile soil and hydrology of the state permits the cultivation of most of Nigeria's staple crops and still allows sufficient opportunities for grazing, fresh water fishing and forestry development (NSBS, 2012).

Data

A three-stage sampling technique was used to select the sample of households for this study. In the 1st stage all the three agricultural zones in Niger State were purposively selected and the study area was stratified into two according to prevailing climatic shock experiences that is droughts prevailing or vulnerable villages and floods vulnerable villages, these villages were identified with the use of digital elevation map (DEM) as shown in figure 1 below. In stage 2, 15 villages were randomly selected from drought affected area which is the 1st stratum and 15 villages were equally randomly selected from floods affected area which is the 2nd stratum. In the last stage, in each village 10 farming households were selected with simple random technique and a total of 300 respondents were selected for the study but 293 had adequate information fit for analysis. Primary and secondary data were used for the study. The primary data was collected through questionnaire by the use of interview schedule method. Information was collected on the socio-economic characteristics of farming households in the study area, sources of livelihood available to households, household total income; expenditure of farming households.

Analytical Technique

Descriptive statistics which include frequency table, graph and percentages were used to

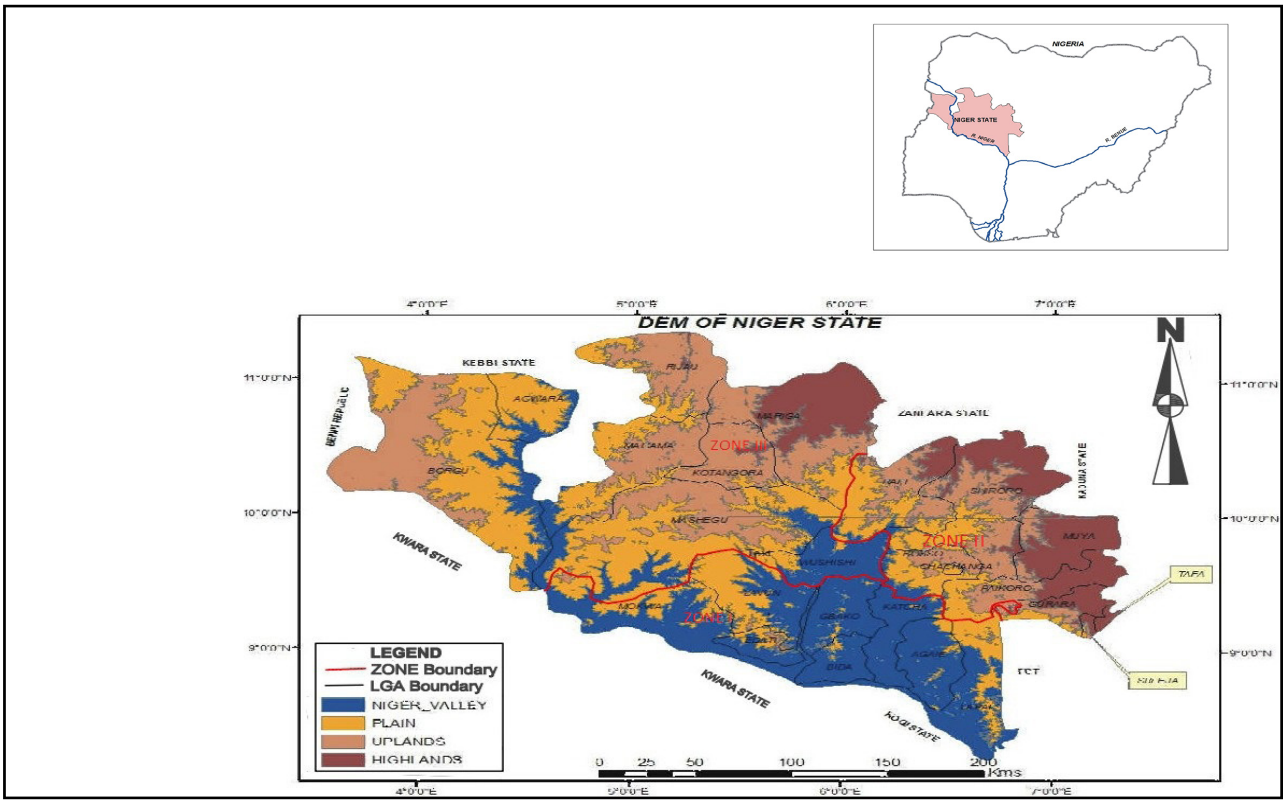

Figure 1: Digital Evaluation Model (Map) of Niger State.
Source: Modified of Ikusemoran et al. (2014)

analyze socioeconomic characteristics of the respondents, mitigation strategies applied by the households and cost-benefit analysis of the most applied strategies.

Model Specification

The models used to achieve the objectives of the study are given below:

Benefit-Cost Analysis (BCA)

In estimating the cost effectiveness of dry season irrigated farming and drought tolerant crops, BCA was employed.

For each adaptation strategy, the total costs incurred when using those strategies and benefits were identified and to compute the net benefit for that particular adaptation strategy equation 1 was used.

$NB_i = \sum TB - \sum TC$ (1)

Where;

NB_i = the Net benefits

TB = the Total benefits

TC = the Total costs.

The BCR for each adaptation strategy was subsequently computed following the equation below:

$$\sum BCR_i = [\sum B_t/(1+r)^t]/[\sum C_t/(1+r)^t] \quad (2)$$

Where;

BCR_i = Benefit Cost Ratio of the ith strategy
B_t = Total benefits at year t,
C_t = Total costs at year t,
r = Discount rate
$(1 + r)^t$ = Discount factor at year t.

The Net Present Value was estimated as:

The Net Present Value (NPV) = $\sum (B_t - C_t)/(1+r)^t$ (3)

Where;

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B_t = Total benefits in year t
C_t = Total costs in year t
r = Discount rate
(1+r) t = Discount factor for year t

Decision was made and conclusions drawn on each adaptation strategy. Generally, the higher the BCR, the better the strategy while the lower the BCR, the less economically viable the practice. The adaptation strategy with a positive and highest NPV is the most economic and efficient. Sensitivity test was carried out, where the net benefit was discounted at 5 %, 10 % and 15 %. The NPV was computed based on per hectare average returns.

The climate adaptation strategies that were practiced were recorded for one-year period, adoption with immediate costs and benefits, *t*, was assumed to be 1 year in this study.

Results and Discussion

Employed Risk Management Strategies

Figure 2 shows the major mitigation strategies applied by the households, it was observed that many households applied more than one strategies. Over 62 % of the farmers applied drought-tolerant crops while 61 % of the farmers reported the adoption of diversification of crop, plot and livestock. More than 40 % of the farmers adopted dry seasons farming to mitigate the impacts of climate and other shocks. About 23 % said to be doing nothing to mitigate the impact of climate shocks in the study area. It was observed that application of some of the ex-ante coping strategies was determined by the recourses available to the farming households in the study area.

Benefit cost Analysis (BCA) of Mitigation Strategies

Farmers in Niger State experience multiple climate stresses and shocks in different seasons throughout the year. These climate stresses affect the livelihood sectors including agriculture, fisheries, and livestock in different ways. Climate extremes distress the agriculture, farming system, land use pattern, crop productivity and livelihood activities. As presented in figure 2 there are good numbers of ex-ante risk management strategies practiced by people in the area.

To protect the crop from extreme weather events and to sustain food security the farmers in the area practiced irrigated farming during the

Figure 2: Risk Management Strategy Employed by Farming Households

dry season the major crop planted during this period was rice. Table 1 below shows that rice covered the mean area of 1.8 ha and total area of land among the respondents was 222.4 ha. This indicates that majority of those who practiced this strategy are small holder farmers. In the rainy season farming, rice covered the mean area of 1.65 ha and a total of 204.08 ha. In order to smoothing food consumption and income, majority of the farmers used drought tolerant crops; the most common drought tolerant crops used were millets, sorghum and cassava (Okogbenin et al., 2013). Cassava covered the largest total farm size of 205.60 ha and average cassava farm size was 2.36 ha this also indicates that cassava farms were dominated by small scale farming. Millets covered 148.68 ha of land and the average farm size was 1.47 ha which. The farmers also applied sorghum to prevent the effect of climate shocks in the area; this crop covered the total area of 119.80 ha and the average of 1.62 ha among the respondents.

In considering the benefit cost ratio (BCR), sorghum had the highest BCR (1.96), and it had the least average total cost of adoption ($ 54.43) among the respondents, this could make it accessible for a resource poor farmer. Thus, the net benefit ($ 106.07) of adopting sorghum was the smallest among the drought tolerant crops. The drought tolerant crop that had the highest benefit was cassava with $ 187.27 and the cost of adoption was $ 116.33 and had the BCR of 1.60,

Table 1: Area of land used for different adaptation strategies by the respondents

Strategy	Crop	Mean farm size (ha)	Average output (kg)
Dry season irrigation			
	Rice	1.83	1281
Rainy season farming			
	Rice	1.65	577.5
	Maize	1.54	924.0
Drought tolerant crops			
	Millets	1.47	705.6
	Sorghum	1.62	777.6
	Cassava	2.36	4720

and millets had the smallest BCR which was 1.3. To compared rain fed rice and maize with crops planted in other strategies, all the drought tolerant crops and irrigated rice had higher net benefit, benefit cost ratio, and net present values except maize with BCR which is higher than 1.30. In the last season many of the farmers produced rain fed rice at lost due to extreme weather events, the net benefits of production among the respondents were negative ($ 15.18) which suggested that total cost of production was higher than total revenue; and had the BCR of 0.88 which is far below the acceptable BCR which is 1. This implies that rain fed rice farming is risky in terms of investment (Table 2).

However, the dry season irrigated rice farming had the net benefit ($ 219.98) which was the highest, but the cost of adoption ($ 166.51) was the highest as well, this could make it discouraging for the majority of farming households who are resource poor to adopt. It had the least BCR (1.30) which made it to be the least to be adopted when they are considered according to BCR (Table 2).

The result of further estimations shows the strategy that had the highest NPV was dry season rice farming and it implies that when planting rice in the dry season with irrigation, the benefit would be more than the cost by $ 199.98 for each household. This is line with the findings of Adzawla et al., (2020) that discovered that irrigation farming has the highest NPV among many adaptation techniques in Ghana. Millets and sorghum would give $ 101.58 and $ 96.43 respectively on average. Compared with other crops (drought tolerant crops) cassava had the highest NPV which was $ 170.25, this supports the result of Henri-Ukoha (2020). This implies that irrigated rice farming is more beneficial than cassava, than millets and sorghum in the area and it should be considered as the mitigation strategy against climate shocks. The sensitivity analysis shows that even if the discounts rate can change to 5 % or 15 % the NPV for the different crops would be positive. However, the NPV of dry season irrigated rice is the highest and cassava is followed which is a drought tolerant crop; this shows that their total revenues are more than the costs of production and their net benefits are the

Table 2: Benefit Cost Ratio, Net Present Value and Internal Rate of Returns for Irrigated and Drought Tolerant Crops

Crop	Total variable Cost ($)	Total Revenue ($)	Net Benefit ($)	BCR	NPV 5% ($)	NPV 10% ($)	NPV 15% ($)
			Dry season irrigation				
Rice	166.51	386.49	219.98	1.30	209.42	199.98	191.38
Rainy season farming							
Rice	126.33	111.16	-15.18	0.88	-	-	-
Maize	119.54	158.06	38.52	1.32	36.67	35.01	33.51
			Drought tolerant crops				
Millets	87.25	199.00	111.74	1.30	106.38	101.58	97.22
Sorghum	54.42	160.50	106.07	1.96	100.98	96.43	92.28
Cassava	116.33	303.67	187.27	1.60	178.29	170.25	162.93

highest therefore, they are more beneficial than millets and sorghum (Table 2).

Conclusion

The study has found that: majority of the farming households are small-scale farmers, climate change and variability risks are prominent among the risks faced by farmers, and both drought tolerant crops and dry season farming are cost effective among the adaptation techniques. Dry season rice farming has the highest net benefit (NB). The following conclusions have been drawn on the findings; Over 62 % of the farmers applied drought-tolerant crops while more than 41 % of the farmers adopted dry seasons farming to mitigate the impacts of climate and other shocks. It is observed that, dry season rice farming has the highest NB.

However, according to the findings of this study, the following recommendations are outlined to improve the resilience of farming households in the country; since agriculture is the main source of rural livelihood, any improvement of incomes and food supply would be an increase of agricultural production and the main aim should be to improve productivity. A developmental strategy aims at improve agricultural productivity will improve the rural household's resilience. Among the adaptation methods found, dry season farming and use of drought tolerant crops should be encouraged among the farming households and they need to be motivated to adopt these strategies. Government at all levels should rehabilitate the irrigation facilities as well as funding the breeding of drought tolerant crops. All these strategies are to ensure all year-round food production and improved households' resilience capacity and to alleviate food insecurity.

Author contributions

Elaboration and execution, development of methodology, conception and design; editing of articles and supervision of the study have involved all authors.

Conflicts of interest

The signing authors of this research work declare that they have no potential conflict of personal or economic interest with other people or organizations that could unduly influence this manuscript.

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