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Full Length Research Paper

A targeted resource, the giant freshwater prawns "*Macrobrachium* species" in the Mangrove Marine Park in D.R. Congo

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This study provides information on the environment, modes of access and exploitation of *Macrobrachium* species, the level of capture, the operators and their organization. The data collected through interviews and direct observations revealed that *Macrobrachium* spp. are caught on the banks of the Congo River near the islands of Kimuabi, Malela and Mateba in Zones A and B of the Mangrove Marine Park (PMM). This fishery is carried out individually by a mainly male population throughout the year using a cylindrical creel baited with palm nuts and dead crabs. The free access to the fishery and the poor knowledge of the factors contributing to the existence of *Macrobrachium* spp. among some fishermen lead them to exert considerable pressure on this resource. This results in the capture of smaller and immature individuals of about 57 and 54 mm, respectively for males and females. It is necessary to deepen this study on the biological, ecological and economic aspects of this resource by involving all the stakeholders concerned by this exploitation in view of a participatory co-management where the fishermen will be particularly concerned.

Key words: *Macrobrachium,* Mangrove Marine Park, D.R. Congo.

INTRODUCTION

The Congolese dense rainforests contain not only rare timber species, but also privileged habitats for wildlife and aquatic fauna. Being one of the countries of the Congo Basin with numerous rivers and lakes, D.R. Congo has significant potential fisheries estimated to about 700,000 t/year (MEDD, 2019). Apart from vertebrates, its aquatic fauna contains 1596 species of aquatic invertebrates, among which 1423 of freshwater and 183 of marine

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Figure 1. Location of the study sites in the Mangrove Marine Park (PMM)
Source: ERAIFT geomatics lab

species (MECN-DD, 2016). Among the aquatic edible invertebrates are freshwater crustaceans including giant freshwater prawns of the *Macrobrachium* genus, which is a very important group because they are traded locally and internationally (Gangbe et al., 2016). Often referred to as *Kosa* in *Solongo*, the *Macrobrachium* spp. prawns are excessively fished in Congo River estuary, which is an integral part of the Mangrove Marine Park (PMM) in Muanda. It is one of the nation's wetlands of international consideration listed in the Ramsar Convention of January 18, 1996 (Ramsar, Iran, 1971) (https://mangrovec congo.net accessed on April 25, 2018). Actually, the PMM is not only a place par excellence of the reproduction of fish (344 species, pers. Com. P. N'Lemvo) and other halieutic species; but also that of refuge for shrimps and fishes during high tide. However, anthropogenic activities, such as oil extraction, illegal fishing, woods exploitation and rowing agriculture on burnt lands exert considerable pressure on this park. The result is water quality and habitats degradation on which these halieutic species depend. The threats to this aquatic ecosystem have become an issue for the national scientific community (Muyaya et al., 2017; Kisangala et al., 2019; Mvambi et al., 2018). However, issues related to the sustainable management of fisheries resources in general and to the giant freshwater prawns *Macrobrachium* spp. more particularly in this ecosystem, have been the least studied, despite the strong fishing pressure these species are subject to. Hence, the importance of this preliminary study which aims to identify the fishing sites, the mode of access and exploitation, the exploiting populations, including their social organization in order to come up with perspectives for further studies.

MATERIALS AND METHODS

Study zone

This preliminary study was carried out in the fully protected Zone A of the Mangrove Marine Park (PMM), precisely near two villages, Kimuabi and Malela, located in Congo River estuary in Malela grouping, Sector of Assolongo, Territory of Moanda, Bas-fleuve District, Province of Central Kongo in Democratic Republic of Congo. It is located between 5° 59' - 6°2' South latitude and 12°29' - 12° 37' East longitude (Figure 1). These sites are characterized by the presence of mangroves dominated by *Rhizophora* species. There are also other species, such as *Raphia sese* De Wild and *Pandanus* species located at the national border with Angola. The overwhelming majority of the population is from the "Assolongo" tribe that is originally from both borders of the two countries, estimated to 4,967 inhabitants in 2020 (Assolongo Sector Office, 2020).

Data collection

Data were collected from October 24 to November 17 and from December 3 to December 25, 2020, the period of the strong fishing activity of these species. Two villages: Kimuabi and Mbanza Malela;

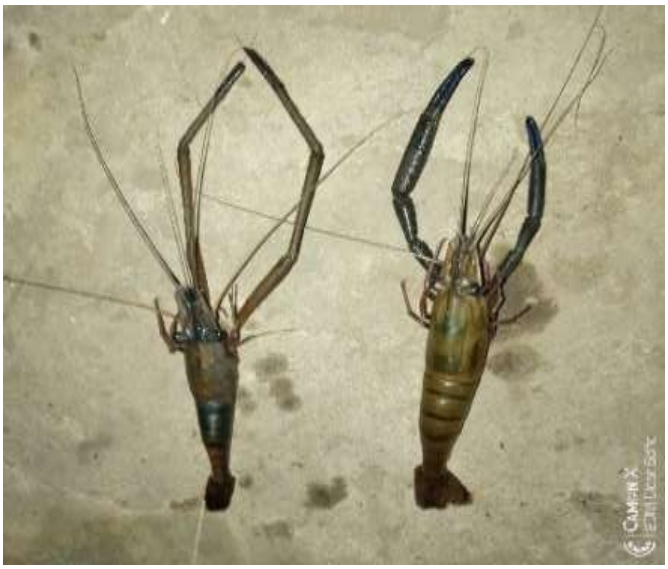

Figure 2. Prawns (*Macrobrachium* spp.).
Source: Authors

Figure 3. Capture creel (Kinkasa).
Source: Authors

and 11 fishermen's camps, namely, Nganda Fubu, Nganda Fumakilembe,Nganda Didame, Nganda Kitshitshi, Kizunga Manianga, Kizunga Malela, Nganda Tshimusende, Nganda Katala, Nganda Kosa 1, Nganda Kosa 2 and Nganda, were involved in this survey.

Data collection consisted of interviews and direct observations. The interviews were conducted in French and in Lingala, which one of the national languages, with about forty (40) people among whom 23 active fishermen of the study area.

Interview guides were elaborated in order to get information on the fishing sites, the fishing period, the actual fishermen, the fishermen's social organization, the access mode, and the fishing techniques used. It was through those interviews and participatory observations that we learnt about the tools and techniques of fishing shrimps. The shape of these tools was described and their size was taken using a tape measure. Eighty-three (83) specimens of *Macrobrachium* spp. were considered from the catch lot of a fisherman in order to get an idea about the size of the prawns caught which was measured using calipers to the nearest 0.01 mm. (Figure 2)

Data processing

The data on the overall population of fishermen and on the prawns size were processed using Word processor and Excel 2016, and presented through tables for analysis and interpretation.

RESULTS

Location of the fishery

According to the respondents, the *Macrobrachium* spp. prawns, referred to as *Kosa* in the local language, are fished on the banks of the Congo River and in its arms locally called *Muila*, near the islands of Kimuabi, Malela and Mateba located in the protected Zones A and B of the Mangrove Marine Park. The fishermen sometimes enter the flooded forest in order to place their capture equipment.

Type of fishing

The *Macrobrachium* spp. prawns are caught individually with a cylindrical creel, locally called *Kinkasa*, baited with palm nuts and dead crabs. It is made of dry branches of *Raphia sese* found in its habitat. Its height varies from 60 to 80 cm with a diameter varying from 20 to 40 cm. The upper base of the creel is closed, while leaving a small opening of approximately 10 cm in the shape of funnel being used as door of entry for the shrimps (Figure 3). Inside the creel, there are two spaces separated by a partition with a funnel-shaped opening of the same size serving as the entrance door. The creel is narrowed and partially closed at the lower base, and there is a small opening of about 15 cm to recuperate the captured prawns. During the installation of the creel, this small opening at the lower base is closed either by means of a plastic bottle with a capacity of 50 cl filled with water, or a piece of flip-flop sole to prevent any escape of the captured prawns. The number of pots used by every fisherman varies between 20 and 400 pots. Given the benthic nature of this type of prawns studied, the creel used for capture is used in 3 different techniques depending on the depth of the water, namely: the techniques of pitting, rope, and the dam technique.

Pitting technique

This technique consists of placing the creel perpendicular

Figure 4. Pitting technique.
Source: Authors

Figure 5. Dam technique.
Source: Authors

to the water flow on the bank in a shallow area (less than one meter) during low tide. The creel is supported by a thin stake of less than a meter, referred to as *Lunama*, which is firmly embedded in the muddy bottom (Figure 4). The control of the creel is done every 24 h, day and night, during low tide by means of a non-motorized canoe propelled by a paddle. After 1 or 2 weeks, the fisherman changes and adopts the rope technique.

Rope technique

It consists of immersing the baited creel near the mangroves in places more than a meter deep, sustained by a long rope attached to the stilt root of the mangrove or another plant species so that it is not carried away by the water current. The control operation is carried out at the same time as that of the creel supported by a rod. Like the previous technique, the installation of the creel takes place during low tide. This procedure uses the wet creel capable of reaching the bottom substrate at a depth of more than a meter. In the first and the second techniques, the creel remains in the water for the entire period of the fishery, except in the case of damage that requires its substitute. The same creel can be taken also to other locations if the catching becomes less abundant. This double option technique is much more practiced by young fishermen under 50 years of age, as it is less tedious than the dam technique described subsequently.

Dam technique

Locally referred to as Zimbanza, the dam technique is quite old, and it is practiced in the small water channels, Nzondo, formed by the waters of the Congo River. Contrary to the previous techniques, the dam technique is practiced by experienced fishermen over 50 years old, preferably during the dry season (February, June, July and August). It targets both prawns and fish of all sizes. Here, the capture is done in 4 periods:

(1) During the day when the water level drops, the fisherman proceeds with the preparation of the location by installing stakes on which the mat made of raffia rods will be fixed, based on the width of the channel and on the water level during the high tide to create a dam;
(2) In the evening, at the beginning of the high tide, the fisherman sets the mat leaving a large opening allowing the shrimps and fish to penetrate the mangroves. He places the creel of about 80 cm height stuck against that mat on its external face, while creating an opening between the two and he makes sure of blocking all ways through which prawns and fish could escape. After fixing the dam, the fisherman returns home while observing water fluctuation carefully;
(3) At the end of the high tide and (4) before the beginning of the low tide, the fisherman returns to the fishing site in order to close the installed dam completely (Figure 5);

During the low tide when the water level in the forest drops, the fisherman collects shrimps and fish while

Figure 6. Rope technique.
Source: Authors

keeping the dam in place. Then, he collects the shrimps and the small fishes caught in the trap. At the end of the operation, the trap and the mat are uninstalled and brought back home for further use.

Technique of conservation of the captured prawns

The prawns caught are kept alive in a creel locally called Kivalanga or kompa in Solongo. It is made of the same materials as the catching net described earlier, with the only difference that the latter is larger, having at least 80 cm height and 40 cm of diameter. This type of creel does not have a partition. The lower base of the creel is completely closed while the upper base is partially closed, leaving an opening through which the prawns entered and are recuperated. The creel can contain about 100 prawns fed either with palm nuts and/or dead crabs. After introducing the prawns and closing the entrance opening with a nylon thread, the creel is loaded with a series of oyster shells, and is sustained by a long rope attached either to the stilt root of the mangrove, or to a heavy metal near the fishing site or the village and then immersed in water of more than one meter deep (Figure 6). It is this device which helps to keep the prawns alive in the water during the entire fishing period while waiting for potential buyers or the shipping toward the marketing place.

Fishing period

Prawns fishing in this area are carried out throughout the year, regardless of the reproductive period of this species and the size of the individuals caught.

Table 1 presents the extreme and average sizes of prawns observed in the batch of catches taken on board by a fisherman from Kimuabi village on 22 December 2020.

Daily yield of the *Macrobrachium* spp. fishery

The overall quantity of *Macrobrachium* spp. caught depends on two things: the number of traps that a fisherman has, and the time of the year. According to the fishermen, the daily quantity of *Macrobrachium* spp. caught is around 3 kg for 50 traps used during the rainy season. This quantity decreases during the dry season. According to one of the fishermen, compared to the 90s, the quantity obtained at present is smaller because they managed to catch more than 10 kg for 9 traps used. The reasons for this decrease in catches over the last 30 years are, among others, the increase in the number of fishermen in their fishing area on the one hand, and the lack of observation of rest periods to help the prawns to reproduce and multiply in number. Due probably to ignorance, some fishermen, however, attribute this decrease to divine will.

***Macrobrachium* spp. prawns fishermen**

This fishery is practiced by a cosmopolitan male population, the majority of whom are from Assolongo and Kongo tribes, originally from the villages of Katala and Kibamba which are located in Zone B of the MMP. The interviews showed 74 fishermen specializing in Kosa fishing in the villages and camps we visited in Kimuabi and Malela sites. The majority of these fishermen (24%) were located in Nganda Fubu, followed by Nganda Katala (22%) and Tshimusende (14%) (Table 2). It was reported also that some fishermen do migrate toward other sites such as Katala, Kibamba and the island villages of Angola in case there is a decrease in catch.

Access to fishing

Access to fishing is free because, according to the chief of the Malela grouping, water is a common property without master. However, non-native fishermen pay a fee as right of residence to the village, or to the camp chiefs if they wish to live there in order to carry out fishing activities; the same principle applies to those who request a piece of land to farm. At the village level, this right of residence is valued at the price of two cases of national beer equivalent to $25 ($1 for 2,000 Congolese francs) and 10 L of palm wine that cost $5. At the camp level, on the other hand, the right of residence is fixed at 3 bottles and a case of national beer. In addition, every fisherman

Table 1. Extreme and average sizes of prawns caught on December 22, 2020 (N=83).

Sex	Number of individuals	Minimum length (mm)	Maximum length (mm)	Mean (mm)	Sd (mm)
Male	43	57	120.6	92.79	11.37
Female	40	54	115.23	85.66	14.01
Grained female	18	65	108.46	87.47	12.15

Source: Authors

Table 2. Distribution of *Macrobrachium* spp. fishers in the camps and villages visited in PMM area A.

Village/Camp	Number of fishermen	Percent
Fubu	18	24
Didame	4	5
Dilondo	3	4
Fuma Kilembe	1	1
K. Malela	3	4
K. Manianga	3	4
Kimuabi vil.	5	7
Kitshitshi	1	1
Kosa 1	3	4
Kosa 2	4	5
Mbanza Malela	3	4
Ngd Katala	16	22
Tshimusende	10	14
Total	74	100

Source: Authors

pays 5000 FC ($2.5) every year as annual tax to the chief of Assolongo sector for the use of a canoe.

Social organization

Most of the fishermen interviewed declared that they do not belong to any association simply because they do not trust their association leaders. However, they are organized informally using the "tontine" system, in which a determined number of fishermen, consisting of groups of friends or family members, commit themselves to paying each one of them a well-fixed quantity of prawns (e.g. 10 kg of prawns) at a regular frequency (e.g. at the end of each week). Based on this rotary tontine rule once set up, one of the participants receives the prawns collected from the other fishermen. This rotary system helps the fishermen to get a big amount of money in a short period of time in order to carry out certain costly projects. In Kimuabi, for example, there is only one such association of located in Fubu camp, known as Association of Fubu Prawns fishers at Kimuabi (APECREFUKI/ASBL). This association was founded in 2017 thanks to the FAO agents' advice. At present, it has 32 members including 23 fishermen and 9 fishmongers.

DISCUSSION

It came out of this study that the *Macrobrachium* spp. capture is done by means of creels baited with palm nuts and dead crabs. The creel technique has been reported by several authors among whom Central and West African peoples (Bahuchet and Rameau, 2016; Akonkwa et al., 2017; Attingli et al., 2017; Allagbe et al., 2020). Factors explaining the daily use of the creel include: the availability of the equipment, the easy conditions of its acquisition and the mastery of this fishing tool (Adou et al., 2021).

This fishing tool used throughout the year has a non-selective character which results in the capture of not only male and female individuals whose average size is, respectively about 100 and 86 mm, but also of smaller and immature individuals varying between 57 and 54 mm, respectively for males and females. However,

Figure 7. Conservation creel (Kivalanga).
Source: Authors

Akonkwa et al. (2017) and Attingli et al. (2017) reported that the creel is among the least selective fishing tools in that it is at the basis of the decline in fishery resources. This constitutes a potential danger for the future of these particular species.

The practice of fishing during the spawning period does not pose any problem to the fish stock provided that the latter is in good conditions and that quota is respected (Ethic Ocean, 2018). In the Congolese context, where the exploitable potential of some species, such as the *Macrobrachium* spp. is unknown, fishing during the spawning season should be made an issue.

The assumption about attributing the reduction of catches to the divine will was also made by Micha (2019) among Lokele fishermen living in the Yangambi Biosphere Reserve. Such a belief is not likely to contribute to a sustainable use and perpetuation of fisheries resources.

The predominance of males in prawns fishing was also observed by Chuku et al. (2021) in Nigeria. That could be explained by the fact that fishing for the *Macrobrachium* spp. during the day and at night requires a lot of physical effort of setting and checking the creels over a long distance while rowing at the same time to remote fishing zones (Figure 7).

The idea of the PMM water body as a common property without owner urges the fishermen to exploit this resource quite freely without caring about future generations. That is due to the lack of law enforcement and regulations, as well as to the lack of qualified staff at the national level to ensure surveillance. Until now, the nation has been using the old regulations on fishing that was set in 1937 (DRC fishing law). The provisions of this colonial law have not been updated, especially on issue regarding sustainable and responsible fishing.

The tontine system is one of the alternatives to the issue of access to funding to be considered for rural communities in Sub-Saharan Africa (Kadandji, 2021; Sarr and Fall, 2021). However, that does not help the fishermen to invest fully to the height of their needs, nor protect themselves against climatic changes and economic fluctuation. Hence, the need to gather in a formal association in order to benefit from the actions of struggle against poverty and climatic hazards set up by national and international organizations.

Conclusion

This study on the fishing of the giant freshwater prawn "*Macrobrachium* spp." showed that the exploitation of this resource in the PMM is done in an individual and uncontrolled way by a mainly male population using a cylindrical trap baited with palm nuts and dead crabs. This fishing practice is not sustainable because it does not take into account the reproduction period and the size of the individuals caught. Although fishermen have noted a decrease in the level of their catch over the last 30 years, some of them are unaware of the causes that affect this reduction. Hence, the importance of deepening this study from the biological, ecological and economic point of view of this fishery resource by involving all the stakeholders concerned by this exploitation, in view of a participatory co-management where the shrimp fishermen, primary actors of this exploitation, will be particularly concerned. This is our challenge for the years to come.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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Full Length Research Paper

Perception of native arid nature in urban surroundings by young urban educated dwellers in Jordan

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More than 33% of the Earth's land surface is considered arid or semi-arid regions, whereas drylands occupy up to 41.3% of the land surface. Increasing urbanization and technological advances cause a disconnection between the built environment and native nature. Also, although species of arid regions are characterized by a high degree of adaptation, they are rapidly moving toward extinction. Since one's perception of nature determines the way people interact with their surroundings, the perceptions of young Jordanians aged 18-39 was explored, and this age group is the largest in Jordan. This study was conducted using a survey. The target group was recruited in Jordanian universities via social media pages to allow the maximum participation of the targeted age group. What forms of nature the young individuals preferred and what forms were accepted, tolerated, and rejected in urban areas were examined. It was found that the participants are drawn to humid and non-arid nature, that is to nature that is generally non-existent in their urban surroundings.

Key words: Urban nature, nature perception, arid nature, young urban dwellers.

INTRODUCTION

Over two-thirds of the world's population will reside in regions considered water stressed by 2025 (Watkins, 2006); assuming that almost 90% of the population increase will be in arid regions; causing an increasing amount of urban sprawl that will affect native species and biodiversity (Alrusheidat, 2004). Most cities are built in a "*disequilibrium*" state from the natural environment (Wilson, 1984). Urban sprawl displaces native species and replaces them with non-native ones; a study conducted on thirteen towns on different continents showed that native plant species richness declined between 3 and 46% in a span of 50–150 years (Bertin, 2002). Urbanization not only affects native flora and fauna species but also biodiversity conservation (Cincotta et al., 2000); the increasing rates of urbanization are leading to a disconnection from the natural world. Naturalness represents the ecosystems with the original natural state, either, by historical benchmarking referencing of the pristine landscapes not touched by humans; or by the ecosystem self-organization, which

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allows addressing original ecosystems that adapt in an urban context. Many conservationists follow the historical benchmarks approach to define the wilderness and naturalness of an ecosystem (Reif and Walentowski, 2008), yet different kinds of nature can be included in the urban context (Ridder, 2007).

The "*Four Natures approach*", described in (the 1990s) (Kowarik and Langer, 2005) allows using the wilderness and naturalness terminology in the urban context. By addressing four kinds of nature in terms of landscape inheritances, human interventions, and environmental characteristics, these include the remains of pristine ecosystems, rural landscapes, novel urban green spaces on vacant open spaces within the urban context, such as gardens, parks, and graveyards created by humans (Kowarik, 2013). These green and blue urban spaces are nature-based solutions for city challenges, as they preserve biodiversity, fight climate change, and improve living conditions, health, and well-being (Artmann and Breuste, 2020).

Arid regions are contrary to humid regions, both characterized by precipitation amounts. There are three types of arid regions, the "*hyper-arid*" which forms 4.2% of the land cover, the *"arid zones"* which are estimated at 14.6%, and the *"semi-arid zones"* which cover 12.2%; overall, almost one third of the total land area in the world is an arid land. The forms of urban nature in arid regions are categorized into "*ephemeral annuals*", "*succulent perennials*" and "*non-succulent perennials*", which include a mixture of grasses, herbs, and small, short trees and shrubs (FAO, 2020).

Although arid species are categorized with a high degree of adaptation to harsh conditions, arid regions suffer more biodiversity loss than more species-rich regions (McNeely, 2003).

The five common perceptions methods of nature state five different approaches to preserving nature. The first method assumes that "*Everything in nature is connected*" based on cultural differences and beliefs, assuming that human activities cause a series of impacts that are reflected on the ecosystems and social systems. The second assumption is "*Nature is benign and perverse*"; this declares that nature is either gentle and promotes well-being or hostile. The third perception assumption is "*Nature is Fragile*"; this states that nature is delicate and vulnerable to ecosystem changes that throw it out of equilibrium. The fourth perception was promoted during the industrial era which states that "*Nature is durable*" assuming that nature can be shaped and changed according to various needs and desires, supposing that environmental damage can be repaired and rebalanced by science and technology. The fifth perception view is "*Nature is capricious*"; and changeable, according to different conditions in the ecosystems including weather, without having strong natural forces to maintain the ecosystems in a particular way rather than a random way (Marten, 2010).

Interacting with nature has positive impacts on humans, both physically and mentally (Beatley and Newman, 2013). Human well-being is measured in two perspectives: the clinical perspective represented the absence of negative conditions, and the psychological perspective represented in the prevalence of positive attributes (Barwais, 2011), and having social interactions of good quality (Johnston, 2019). Well-being in psychology refers to people's mood and interaction with their surroundings when exposed to certain events or different natures. Subjective well-being is typically considered as the good mental status that reflects people's satisfaction with their lives and experiences (Diener, 2000).

Urban nature is of great importance for urban dwellers' well-being. Green spaces, gardens, and parks enable them to interact with nature (Bhatti et al., 2014), thereby providing considerable physical and psychological benefits (Beatley and Newman, 2013).

People get more benefits when they interact with their preferred forms of nature (Martin et al., 2021). Nature perception is defined by people's previous experiences and stories with their surroundings, based on the stored information and interpretations that formulate actions and attitudes toward the surrounding natural systems (Marten, 2010), which in turn makes some forms of nature more preferred than others (Batt, 2009).

The selection of certain flora species in urban areas determines the diversity of fauna and avifauna species that exist within the ecosystem (Temple and Wiens, 1989). Moreover, the selection of diverse vegetation, distribution, localization, and structure, whether trees, shrubs, or ground cover, creates buffer zones and noise-controlled areas that attract various birds and contribute to protecting biodiversity (Hanle et al., 2021). In addition, the satisfaction of the urban dwellers is subjected to their needs acting as farming and food resources (Van Veenhuizen and Danso, 2007) or as a recreation destination and a stress relief tool (Beatley and Newman. 2013). Including nature improves the quality of life on the one hand, whereas the quality of life is associated with the benefits that people gain from nature on the other hand (Cárcaba et al., 2017) nevertheless, urban dwellers' happiness is a subjective term that can measure their satisfaction with their surroundings (Fontinelle, 2022).

This paper investigates the young urban educated dwellers' perception of their surrounding nature and explored their preferred forms of nature.

METHODOLOGY

Case study

The study sample was conducted in Jordan, a country with hot dry climate conditions that is considered one of the most diverse arid regions in the Middle East, due to the extent variety of ecological and regional natural elements (RSCN, 2013).

Jordan has one of the youngest populations in the world, with 63% of its population under the age of 30 (Unicef, 2020). It's the

Table 1. Participants in each age group.

Age groups	% of total responses	Number of responses (573)
below 18	4.20	24
18-29	42.60	244
30-39	24.60	141
40-60	27.60	158
above 60	1	6

Source: Authors

Table 2. Participants living context for the age groups 18-39.

Region	5 of total responses	Number of responses (385)
City context	84	322
Rural areas	14	54
Desert areas	2	9

Source: Authors

24th most urbanized country in the world; 91% of the population lives in urban areas.

Material

This survey consisted of thirteen questions. Young, urban, well-educated, and social media users were those selected for the sample. Jordanian youth's media and technology consumption patterns state that 91% of Jordanian youth use social networking sites daily (Abu lail, 2017) The survey was posted for up to 10 days from October to December 2020 via Jordanian university's social media networks, including the social network pages of the University of Jordan in Amman, Hashemite University in Zarqa, and the University of Petra in Amman. The questions were organized along three thematic blocks, the first block was to test nature cognition through understanding which forms of the natural elements both biotic and abiotic represent nature for the participants, the second one was to test the desired forms of nature and the last block was to test their interest in nature and biodiversity conservation approaches. The survey combined multiple-choice questions that allowed selecting more than one answer and check box questions to clarify the preferred answer, offering respondents the possibility to choose and rank among several options.

The participants are anonymous but they provided information on their age as shown in Table 1. In total, 573 persons participated of which 385 were between 18 and 39 years old. This group was selected as a representative young urban educated population of the country for the study.

To focus on urban living conditions, we categorized the participants on their living context, urban, countryside, and desert areas. The great majority of young participants of the study were urban living (Table 2). They were students and educated young urban dwellers.

Many photos were provided to identify the participants' cognition and understanding of native nature. A provided photo series represented natural elements of native arid regions varying from sceneries to selected plant and animal species, representing typical natural elements of the region, including seasonal aspects and artificial and urban elements (Table 3).

To test the knowledge and recognition of species/species groups and structural diversity, the participants were asked about whether they observed characteristic animals representative of a species group and structures in their surroundings: animals: e.g., house sparrows, mice/rats, snakes, sheep, bee; plants: black iris, sage, olive trees, juniper, and grass.

The authors aimed to investigate the planted vegetation's suitability to arid/semi-arid climates in the participant's surroundings by providing a question on irrigation frequency. Two questions of the survey raised queries on the acceptance of wildlife in the participants' living context.

One question of the survey aimed to investigate participants' preferred outdoor nature qualities in an urban context. The survey elicited responses to three types of features: forests with native species; designed landscapes and gardens; and recreational facilities such as shopping centers and malls. Another question identified the participants' preferred outdoor activities; the survey listed three outdoor activities: picnics, driving, and sports such as jogging, walking, or cycling.

In addition, the authors requested the participants to answer queries on the public awareness importance and to understand their interests in maintaining biodiversity, conserving nature, and reforestation initiatives. The last question aimed to illustrate the preferred plants in the participants surrounding whether they prefer arid regions' native plants that do not need a lot of water or non-native plants that need irrigation.

RESULTS

Results representation

The results show what young urban dwellers consider nature waters with surrounding green forests (85.5%), native semi-arid forest conditions (68.6%), native arid nature (Cactus plants 38.4%, native vegetation 35.3% - especially in flowering aspect, wild native plants 27.27%), and irrigated urban park green (32.7%). Participants did

Table 3. Selected species group by representative photos with reasoning.

Selected species group by representative photo		Reasoning
1. Animals		
1.1 House Sparrow		A popular avifauna in Jordan
1.2 Mice or Rats		High adaptation to environmental changes. Mice and rats are associated with human dwellings
1.3 Snakes		The snake was selected to illustrate the urbanization influence on arid and semi-arid native species' biodiversity
1.4 Sheep		To illustrate the grazing behavior in arid urban areas which threatens arid and semi-arid regions plants and vegetation
1.5 Bees		Bees are important pollinators in many ecosystems, they were selected to investigate the influence of urbanization on their natural habitat
2. Plants		
2.2 Black Iris		The black iris was chosen as it is considered the national wildflower of Jordan; it is endemic to Jordan and is an endangered species
2.3 *Salvia officinalis* (Sage)		Sage was chosen as it is considered one of the most common wild native plants in the region

Table 3. Contd.

2.4 *Olea europaea* (Olives trees)		The olive tree was included in the photos; due to cultural and religious beliefs of considering the olive tree as a blessed tree. In addition to the benefits, people can gain from planting it
2.5*Juniperus horizontalis* (Juniper bushes)		A convenient ground cover that suites arid region
2.6 Grass		Does not suit arid and semi-arid regions due to its high consumption rates of water

Source: Authors

Table 4. Which of the below pictures represents nature?.

Pictures as representatives of	% of total responses	Number of responses (n = 385)
Lake with surrounding forest (non-arid region)	85.50	329
Native coniferous forests in semi-arid region	68.60	264
Waters in a mountain creek	51	197
Cactus plant	38.40	148
Native vegetation in flowering aspect in spring	35.30	136
Designed irrigated green in urban park	32.70	126
Wild native plants	27.27	105
Sandy desert	26.20	101
A spider	20.26	78
Arid mountains (accessible by infrastructure)	18	70
A snake	17	66
Native vegetation in dry season	6.20	24
Urban residential neighborhood with street trees (low building density)	3.60	14
Densely built up city center (Amman)	2.60	10

Source: Authors

not recognize non-vegetated urban site as nature (only 2.6%, 3.6%) (Table 4).

The young urban dwellers normally do not have rural species or species from far outside cities in their surroundings. Besides the typical urban species (e.g. sparrow, mice, irrigated grass) a majority of people identified typical rural species (e.g., sheep, bee, sage, olive) as “their environment.” This suggests that urban dwellers are still mentally or even physically (by family relations) connected to rural nature. Many of them and their families moved to urban areas only in this or their parent's generation, and they come from the countryside

Table 5. Do you have any of the below species in your environment?

Picture	%of Total Responses	Number of responses (n= 385)
Typical urban species		
House Sparrow	49.30	190
Mice or Rats	33.20	128
Irrigated grass	53.20	205
Typical rural species		
Sheep	68.30	263
Bees	76.30	294
Sage	58.44	225
Olives trees	82.00	316
Natural native species		
Snakes	20.20	78
Black Iris	22.00	85
Juniper	18.70%	72

Source: Authors

Table 6. Do you irrigate the plants in your home garden or the street where you live, and if yes, how often?

Frequency of irrigation in the urban surroundings	% of total responses	Number of responses (n = 385)
Yes, every day	16.60	64
Yes, Twice a week	29.10	112
Yes, Once a week	16.40	63
Yes, rarely	9.60	37
No, the Plants rely on the rainy season	7.80	30
We don't have a house garden or trees on my street	20.50	79

Source: Authors

Table 7. Do you accept, reject, or neutralize wildlife presence in your living sphere?

Acceptance of wildlife in the urban living sphere	%	Number of responses (n = 385)
Accepted	16.10	62
Rejected	56.60	218
Neutral	27.30	105

Source: Authors

to which they are still linked. The typical urban species are less and the typical natural native less identified as “environment” (Table 5).

Question about irrigation of home gardens or trees in the street where the people are living, people in the majority have a garden, green spaces around the house, or at least trees in the street within their living context (79%, n=306). This means that they are not completely disconnected from nature. They also understand that most of the urban plants rely on irrigation (92.2%) and need mainly twice-a-week irrigation (Table 6).

The majority of questioned young urban dwellers reject wildlife in their urban living context. This is not surprising, but shows the disliking of nature on one side and also the fear of wildlife because of real or imagined danger (Table 7).

Unlike wild animals, wild plants are much more accepted in urban surroundings. A majority accepts them and only a small minority rejects this (Table 8).

The question about nature on the landscape level a

Table 8. Do you accept, reject, or neutralize wild plants that do not need irrigation in your living sphere?

Acceptance of wild plants in the urban living sphere	%	Number of responses (n = 385)
Accepted	53.20	205
Rejected	8.10	31
Neutral	38.70	149

Source: Authors

Table 9. Which of the below forms of nature do you prefer?

Preferred nature (landscape level)	%	Number of responses (n = 385)
Pristine landscapes	83.90	323
Designed landscapes	16.10	62

Source: Authors

Table 10. what outdoor qualities do you prefer in your surrounding?

Preferred outdoor qualities	%	Number of responses (n = 385)
Forests with native plants and animals	53.00	204
Designed landscapes, and gardens with non-native plants	29.90	115
Shopping centers, malls, and city recreational facilities	17.10	66

Source: Authors

Table 11. What outdoor activities do you prefer?

Preferred outdoor activities	%	Number of responses (n = 385)
Picnics	70.40	271
Jogging, walking, and cycling	15.40	60
Driving along with the car	9.40	36

Source: Authors

clear majority (83.9%) prefers natural (“pristine” landscapes in comparison to “designed” landscapes (Table 9). But the survey does not define what exactly is understood by “pristine” or “designed.”

Even when shopping centers and malls enjoy unbroken interest and are attractive among young urban dwellers, a majority don’t want to have it in their surroundings and prefer nature (Table 10). This is possible because of high degrees of urban mobility and because people do not need to shop daily. But perhaps they need nature contact daily. Here also the native forests are preferred against designed nature.

Having a picnic in nature is a social activity that is clearly preferred (70.4%). This shows that more a contemplative than active consumption of nature, maybe in urban surroundings, is attractive to the majority. This is related to climatic conditions not surprising (Table 11).

Most respondents (72.7%) claimed to be active in caring for nature conservation and biodiversity (Table 12). An overwhelming majority expressed interest in reforestation initiatives (70.1%). This must not mirror the real situation but represents a “possibility” to become active (Table 13).

A clear majority (68.8%) prefers irrigated non-native plants compared to native plants that make up “dry gardens”. The flourishing and all-year green is depending on irrigation and is mostly non-native. But both are less important for the majority (Table 14).

Results analysis

The result of one-way ANOVA revealed significant difference between context of young people and their selection of nature; such as wild native plants "F

Table 12. Do you care for nature conservation and biodiversity in your surrounding?

Care for nature conservation and biodiversity	%	Number of responses (n= 385)
Yes	72.70	280
No	2.90	11
Maybe	24.40%	94

Source: Authors

Table 13. I like to participate in reforestation initiatives. I think it is important for the environment.

Interest in participation in reforestation initiatives	%	Number of responses (n = 385)
Yes	70.10	270
No	7.80	30
Maybe	22.10	8500.00%

Source: Authors

Table 14. What plants do you prefer in your urban surroundings, native plant or non-native plants?

Preferred plants in the surroundings	%	Number of responses (n = 385)
Arid region's native plants	31.20	120
Non-native plants that need irrigation	68.80	265

Source: Authors

(382,2) = 5.12, α = 0.00", densely built up city Centre "F (382,2) = 4.78, α = 0.00", waters in a mountain creek "F (382,2) = 6.38, α = 0.00", native vegetation in flowering aspect in spring "F (382,2) = 6.20, α = 0.00" , native vegetation in dry season "F (382,2) = 4.00, α = 0.00", Designed irrigated green in urban park " F (382,2) = 5.74, α = 0.00", a spider " F (382,2) = 4.31, α = 0.00", sandy desert " F (382,2) = 5.00, α = 0.00", arid mountains (accessible by infrastructure)" F (382,2) = 4.10, α = 0.00", lake with surrounding forest (non-arid region) "F (382,2) = 9.76, α = 0.00", native coniferous forests in semi-arid region "F (382,2) = 8.83, α = 0.00", a snake "F (382,2) = 4.05, α = 0.00", urban residential neighborhood with street trees (low building density)"F (382,2) = 3.85, α = 0.00", cactus plant "F (382,2) = 6.12, α = 0.00" it can be seen, young visitors who live in the city have the highest represent nature for lake with surrounding forest (non-arid region) (mean = 3.89) meanwhile, they accepted the sandy desert like a nature (mean= 3.61). Arid mountains and Cactus plants are usually found in arid and semi-arid climates, but, interestingly, the young people who live in the countryside (mean=3.69) and who live in desert areas (mean= 3.56) have accepted them as nature (Appendix.1).

Furthermore it can be seen, the young people who live in the country side are more seeing “Bees” (mean= 4.26) and the young people who live in city are more seeing “Olives trees” (mean= 4.11) meanwhile they see fewer snakes in the city (mean= 2.63) (Table 15). However, young people have seen typical urban species in the city (mean=3.38), typical rural species in the countryside (mean=3.93), and natural native species in the desert area (mean=3.36) (Figure 1).

The significant difference between the context of young people and their participation in vegetation conservation (by irrigation) in three parts (d-Yes, e-No idea, and f- No at all), d) every day "F (382,2) = 3.32, α = 0.00", d)twice a week "F (382,2) = 5.82, α = 0.00", d)once a week "F (382,2) = 3.28, α = 0.00", d)rarely "F (382,2) = 2.65, α = 0.00", e) we don’t have any house garden or trees in our street "F (382,2) = 4.87, α = 0.00" and f) the plants rely on rain season "F (382,2) = 2.43, α = 0.00" (see to appendix. 2). It can be seen, the young people who live in country side have highest desire to participate in vegetation conservation by irrigation in every day (mean=3.87) while young people who live in the city have the desire to participate in vegetation conservation by irrigation once a week (mean=3.80) and lowest desire is for young people who live in desert area to participate in vegetation conservation by irrigation every day (mean=1.68). However, young people who live in country side are interested to participate of vegetation conservation by irrigation (mean=3.57), young people who live in desert areas have No idea (mean=3.78) and No at all (3.71) for participating in vegetation conservation

Table 15. ANOVA result for the context of young people and Species seen in the environment.

Where to live	Species seen in the environment	City	Countryside	Desert area	F	Sig
Typical urban species	House sparrow	3.31^{b}	3.51^{bd}	3.12^{b}	4.17	0.00
	Mice or rats	2.87^{ab}	3.10^{b}	3.18^{d}	3.65	0.00
	Irrigated grass	3.96^{a}	3.25^{c}	3.54^{c}	4.89	0.00
Typical rural species	Sheep	3.09^{ab}	4.03^{c}	2.96^{d}	5.21	0.00
	Bees	3.75^{ad}	4.26^{c}	3.61^{ab}	6.17	0.00
	Sage	3.69^{ad}	3.46^{c}	3.03^{d}	4.95	0.00
	Olives trees	4.11^{cd}	3.98^{bd}	3.79^{a}	6.98	0.00
Natural native species	Snakes	2.63^{b}	3.21^{cd}	3.56^{c}	3.36	0.00
	Black Iris	3.07^{ac}	3.69^{c}	3.40^{cd}	3.50	0.00
	Juniper	3.02^{d}	2.68^{c}	3.12^{b}	3.03	0.00

Source: Authors

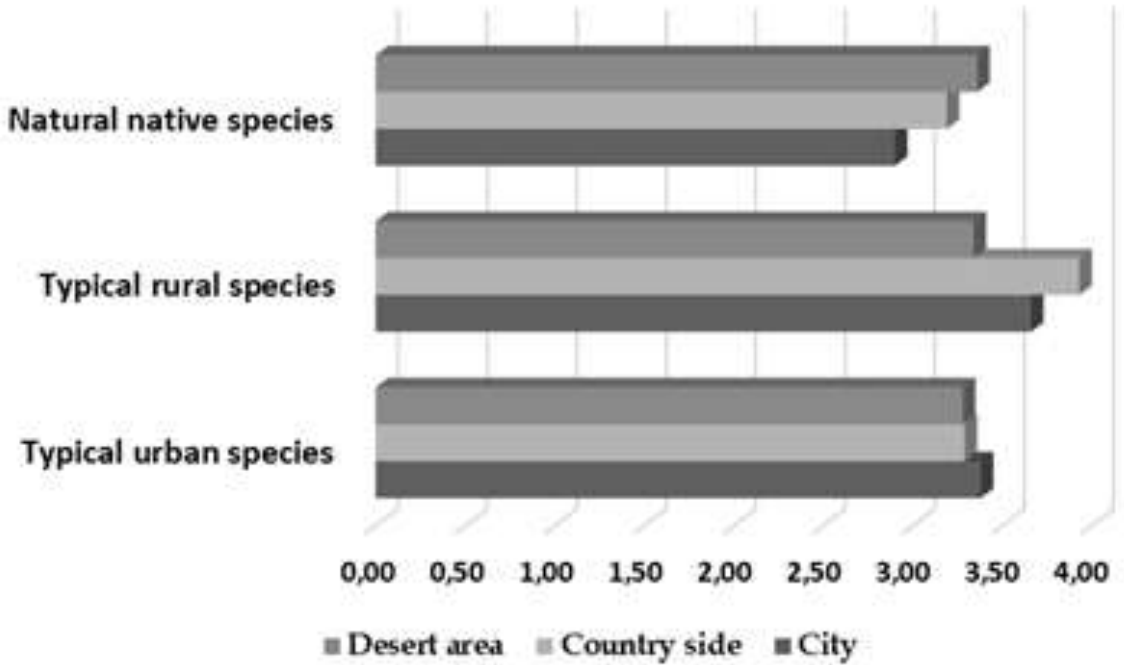

Figure 1 . Mean species were seen around the environment of young people context.
Source: Authors

by irrigation (Figure 2).

Acceptance of young people for wild animal species and wild plants species (no need for irrigation) in their living context was in three parts: Yes, No and Natural, 58.3% of young people can accept wild plants (no need for irrigation) meanwhile 54.1% of young people cannot accept to be exciting of wild animal species in their living context (Figure 3).

In acceptance of the presence of (P-W-W) in preferred nature (landscape level) is; accepting the presence of pets in the pristine landscape is low by young people (mean=2.03, t = -5.89), accepting the presence of wild animal species in pristine landscape (mean=3.36, t= -6.27) and the young people are accepting in the highest level of wild plants (no need for irrigation) in pristine landscape (mean=4.12, t= -6.51) meanwhile accepting the presence of wild plants (no need for irrigation) in the designed landscape is far less (mean=3.11, t= -6.51) (Table 16).

The young people who lives in city preferred forest with native plants and animal "F (382,2) = 5.45, designed landscape, gardens with non-native plants by residents of desert area "F (382,2) = 2.80, α = 0.00" and shopping centers, malls and city recreational facilities by residents

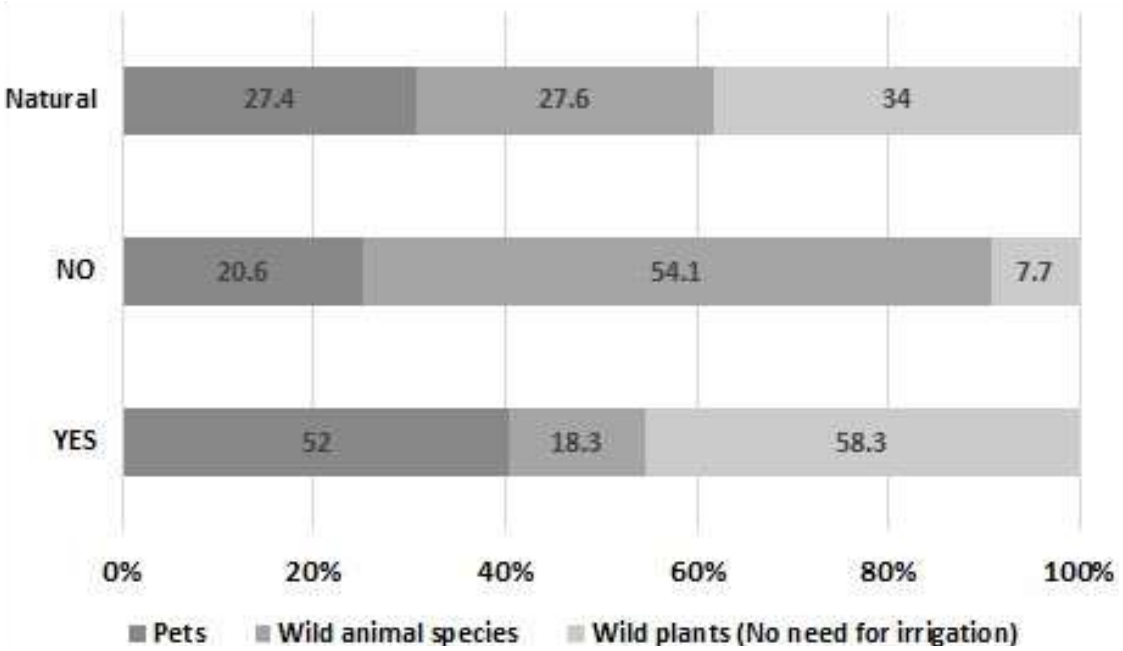

Figure 2. Mean of young people participating in vegetation conversation (by irrigation) in their context area.
Source: Authors

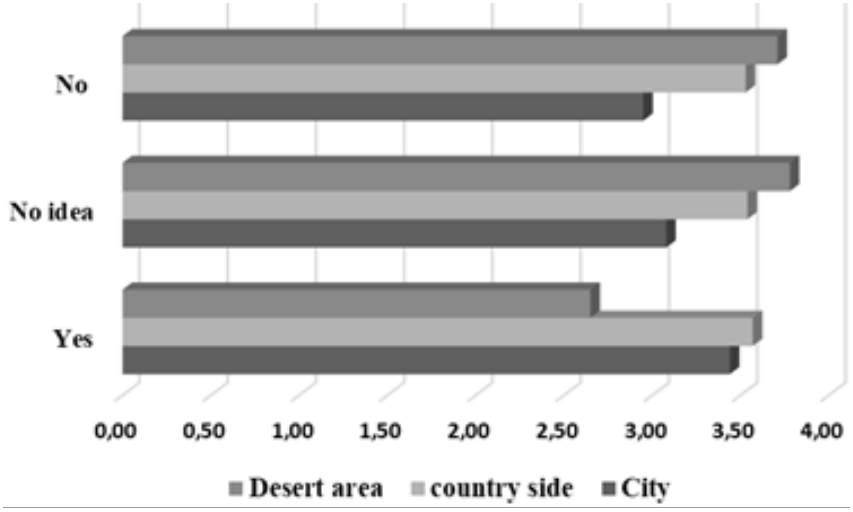

Figure 3. Comparison between acceptance of the presence of wild animal species and wild plants (no need for irrigation) (P-W-W) in the living sphere.
Source: Authors

of country side "F (382,2) = 4.21, α = 0.00" (Appendix. 3).

The result of one-way ANOVA revealed significant difference between preferred outdoor activities and their preferred of outdoor quality in the surrounding, forest with native plants and animals "F (382,2) = 7.02, α = 0.00", designed landscape, garden with non-native plants "F (382,2) = 5.66, α = 0.00" and shopping centers, malls and city recreational facilities "F (382,2) = 4.67, α = 0.00". It can be seen, the highest young people preference to have jogging , walking and cycling in picnic in designed landscapes, gardens with non-native plants (mean=4.23), driving along with the car and watching surrounding in shopping centers, malls and city recreational facilities (mean=3.91) and to have picnics in forest with native plants and animals (mean=3.79) (Appendix. 4).

The young people who live in city, "Picnic" is the most

Table 16. Independent sample t-test between preferred nature (landscape level) and acceptance preferences of (P-W-W).

acceptance of the presence of (P-W-W)	Mean		T	Df	Sig (2-tailed)
	Pristine landscape	Designed landscape			
Pets	2.03	3.23	-5.89	383	0.00
Wild animals species	3.36	3.00	-6.27	383	0.00
Wild plants (no need for irrigation)	4.12	3.11	-6.51	383	0.00

Source: Authors

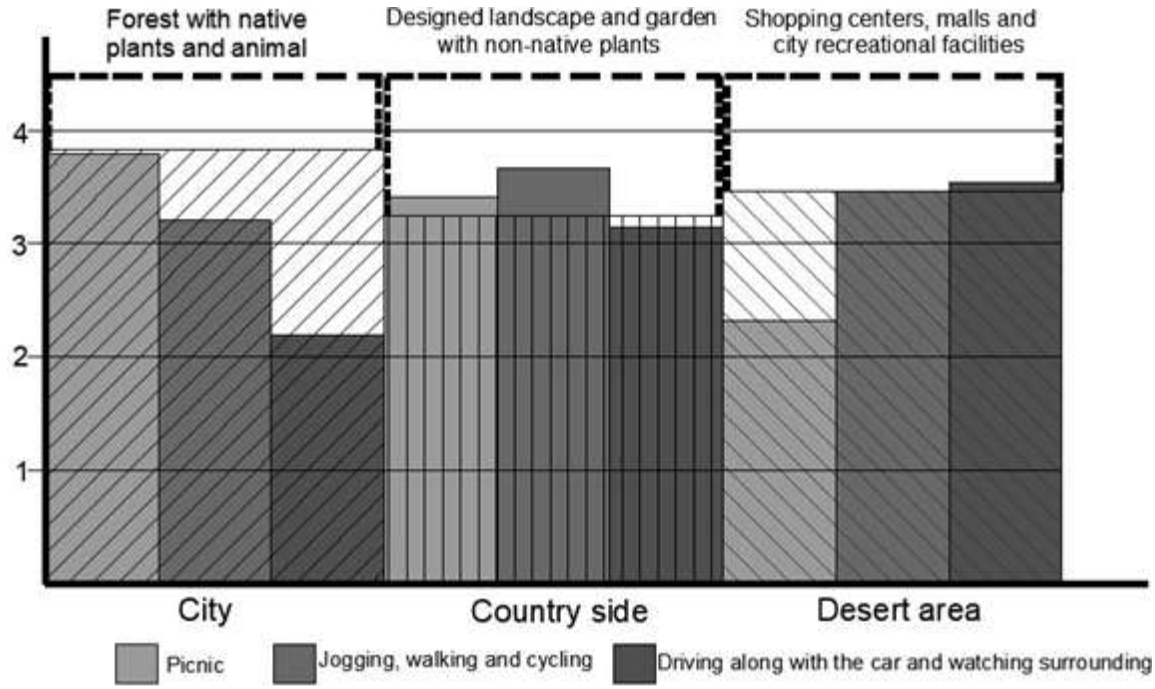

Figure 4. Comparence of preferred outdoor activities and its quality in the surrounding with different the young people accomondations.
Source: Authors

activity's preference in "Forest with native plants and animals" (mean = 3.83). "Jogging, walking and cycling" in "Designed landscape and garden with non-native plants" is the highest preference of the young people who live in the countryside (mean = 3.66). "Driving along with the car and watching surrounding" is most insisting of young people who live in Desert areas in "Shopping center, malls and city recreational facilities" (mean = 3.54) (Figure 4).

Acceptance of young people's desire to participate in the creation and conservation of nature in urban surrounding, 70.1% acceptance to nature creation in urban surrounding and 72.7% to conservation of urban surrounding nature by young people, meanwhile 7.8% of young people cannot accept to have creation of urban surrounding nature and 2.9% about conservation it (Figure 5).

The acceptance of plants with arid regions native plants and non-native that need irrigation for creating and conservation, most of the young people accepted to create urban surrounding by arid regions plants (mean= 3.95, t= -4.28) and the less acceptance of young people is creation of urban surrounding by non-native plants that need irrigation (mean= 2.97, t= -5.18) (Table.17).

DISCUSSION

What is nature in people's minds and what belongs to their surroundings?

The young urban dweller group most preferred "non-arid, humid nature" represented in the picture of a "lake surrounded by forests in the non-arid region", followed by

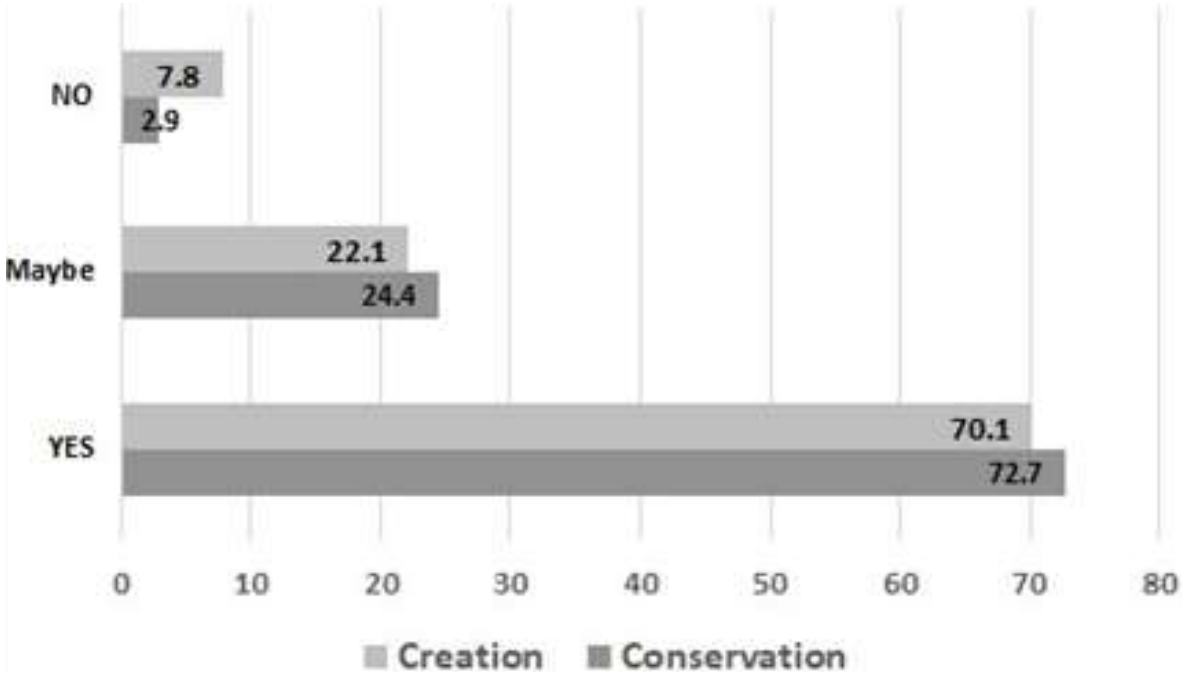

Figure 5. Comparing people's desire to participate in the creation and conservation of nature in urban surrounding. Source: Authors

Table 17. Independent sample t-test between participate in the creation and conservation and acceptance of the plants in the urban surrounding.

Acceptance of the plants	Mean		T	Df	Sig(2-tailed)
	Creation	Conservation			
Arid regions native plants	3.95	3.73	-4.28	383	0.00
Non-native plants that need irrigation	2.97	3.16	-5.18	383	0.00

Source: Authors

native forest nature. “Green nature” related to the water gets the highest rates. The photo of water in a mountain creek (Wadi Almujeb) considered a natural reserve and a tourist destination was selected by more than 50% of the respondents. Moreover, the least percentage of responses considered the urban nature of the daily surroundings. Native vegetation in the dry season in a Roman historical site is even more attractive. The view of the same location with flowering native vegetation during humid spring conditions scored higher. This shows the importance of “green nature” in general for the respondents as a preferred form of nature (Table 4). Moreover, the urban dwellers of Jordanian cities lack the availability of open spaces in their neighborhoods and crowded cities, which they seek in their picnics outside cities or at the side of highways and roads with natural views; this behavior is very common among city inhabitants in Jordan, especially those who are young, due to the planning of Jordanian cities that lacks the availability of these spaces where green nature can be included. The young urban dweller's choices of nature is affected by their needs and what they miss in their surroundings, which explains why the urban image was selected by least of participants and the historical site with native vegetation in both dry and flowering seasons outside the crowded city is selected by the majority of the young urban participants.

On the species level mostly good visible plants are well-recognized, more seldom small not very attractive, and visible plants and rare to observe animals. Some animal and plant species are culturally mostly little noticed or even disliked. People can be afraid of them (e.g. by spikes of plants or expected aggressively or health danger of animals). Many species do not belong anymore to the surrounding of young urban dwellers.

Although it is considered a common urban bird in the region, only nearly half of the young individuals responded that they have seen the house sparrow in their

living environment. It can be argued that the perception of nature on the species level is not very high, especially not in urban surroundings. Also, the other data (Table 5) suggest this interpretation. Besides this is rural nature well represented on a species level as traditional, and culturally rooted and still may be present in family life divided between traditional rural and actual urban. Two third and more respondents know and value the cultural species, especially agricultural ones.

Although mice and rats are associated with human dwellings and have high adaptation to environmental changes; they were reported noticed by one-third in the participants' surroundings. This reflects the ongoing practices to fight rodents in the city context as these species are rejected or disliked by many.

Snakes as rare observed animals, disliked or rejected by many, were only stated seen by less than one-third (20%) of the participants, this illustrates the urbanization influence on arid and semi-arid native species biodiversity, and the distinct of arid regions' native fauna due to the urban sprawl; that extended to the rural and agricultural areas; explaining why sheep were selected by a majority of the participants (68.3 %), threatening native plants with the overgrazing, this gives an indication on the need to organize the grazing activities in the urban context as the increasing amount of overgrazing is directly affecting the native plants and shrubs in arid regions (WADI, 2020).

The responses on the native species give conclusion and raise queries on the suitability and people's choices on the planted trees, and patterns of urbanization that directly affects the biodiversity and ecosystem balance in their neighborhoods.

Olive trees *(Olea europaea)* are native species that are agriculturally profitable; for both urban and rural inhabitants, they formed the most noticed in the participants living context. Olive trees (are very common due to cultural and religious beliefs of considering them as blessed trees; besides the benefits gained from planting them, they benefit from the fruit; these reasons encourage people to plant Olives in their farms, gardens, and in front of their houses (Olives_councel, 2022) and justifies selecting them by a majority of the young urban educated dwellers with (82%).

Other native species such as Bees, were also noticed by more than two third of the participants living environment at (76.3 %).

Black Iris is considered the national flower in Jordan, local government protects it, the wild endangered native plant was reported by less than one-third of the participants with (22%) of the total responses only.

Unlike the Black Iris, more than half of the participants (58.44%) reported seeing Sage (*Salvia officinalis*) in their surroundings. Sage (*Salvia officinalis)* is considered one of the most common wild native plants in the region. Its wide green leaves and strong aroma, in addition to its importance for medical purposes, characterize the plant, which encourages many people to plant it in their surroundings as well (Alfraih, 2020). Although grass is inappropriate for water-scarce regions, almost half (53.2%) of responses claimed its presence in their surroundings, which raises queries on the awareness for water conservation practices and the proper selection for the evergreen ground cover. On the other hand, the Juniper (*Juniperus horizantalis*) was only reported by (18.7%) although it is considered a convenient ground cover that suits the arid region.

People's choices of planted flora in their surroundings show that they prefer humid non-arid native species, which was noted when more than 50% of the young participants claimed they noticed grass in their surroundings.

The native species in semi-arid native landscapes (not cultural landscapes!) are by far less rated than any other. These are not only snakes that are often unlike, but also attractive Iris flowers. This shows that they are not often more a "part of their environment". These native areas are maybe more seldom visited than cultural landscapes

Due to the high population growth and the number of refugees in the surrounding countries; Jordan is ranked number ten among countries in water scarcity countries in the world (Hadadin et al, 2010). Despite these challenges, the results in (Table 6) on the number of times the participants irrigate their plants showed that Only (7.8%) of the participants have plants that are suitable for arid/semi regions, which rely on the rainy season; and 9.6% of participants stated that they rarely irrigate their plants in their house, garden, or the street; whereas the highest responses with less than one third (29.1%) of the participants irrigate their plants twice a week, The result yields conclusion on the participants desired plants in their surrounding environment and the fact that these plants are non-native and don't suit arid regions as it consumes a lot of water.

People are attracted to natural forms they miss in their urban areas, this explains why the majority of the responses with 83.9% of the participants determined that they prefer pristine landscapes more than designed landscapes (Table 9), and more than half (53%) of the participants prefer forests with native species more than designed landscapes (29.9%) and shopping centers within cities scored the least percentage with 17.1% (Table 10).

Quality of life is considered an important indicator of health (Owczarek, 2010). Nature-rich spaces within cities improve the quality of life and increase social interaction and personal empowerment (Keniger et al., 2013). Additionally, the quality of life is associated with the benefits people gain (Cárcaba et al., 2017), nevertheless, it is a subjective term that can measure happiness when meeting their interests and needs (Fontinelle, 2022), Which explains why two third of the participants (70.4%) prefer picnics in natural spaces, over Jogging and driving 15.4% and 9.4% respectively (Table 11).

The results on public awareness toward biodiversity and nature conservation showed that two third of the participants have a good degree of awareness of the importance of biodiversity conservation (72.7%) and care for nature in their surroundings (Table 12); they also like to participate in reforestation activities and they think it is very important for the environment (Table 13), yet their selection on preferred nature showed that (68.8%) of them prefer non-native plants which need irrigation (Table 14). This indicates that they prefer humid nature over native arid nature. The result implies increasing efforts and awareness programs to explain the importance of native nature integration and restoration, through planting arid native flora to conserve native nature and reduce biodiversity loss in arid regions. Although arid regions' flora species are categorized with a high degree of adaptation to harsh conditions nevertheless, the loss is higher than in other regions(McNeely, 2003).

Where which arid nature should be located and in which dimension?

Moreover, nature integration in arid regions involves actions on three dimensions, decision-makers and governance level, designers and practitioners' level, and individuals and local communities level. Actions vary from imposing regulations, and controlling grazing to protecting landscapes and native flora; other actions involve reforestation and dry land plantation and restoration and initiating awareness programs (FAO, 2009).

Action towards reforestation and nature restoration was initiated during the past decade, these initiatives allowed handling desertification and nature restoration processes through information coordination, systems observations, and employing solutions based on appropriate technologies, the cooperation involved global, national, and local level resulting developing measures to deal with desertification while improving socio-economic conditions. The solutions involved activities such as strengthening environmental information systems in various regions, measuring the ecological and socio-economic consequences, and the impact on climate change; supporting research, and Strengthening regional programs and international cooperation. Other actions involved financing related conservation and restoration projects, and increasing awareness, globally and within local communities to allow employing the best conservation and restoration practices (UNCCD, 2021).

Adopting the afore-mentioned actions in arid urban areas allows integrating arid nature into urban life, to promote an active, healthy, and, built environment, while protecting native arid biodiversity and ecosystems when considering native nature integration. The study illustrated that people are attracted to pristine landscapes that are rich in greenery and native flora and fauna species, yet, they are also attracted to nature, which they miss in their living context; this requires increasing efforts working on the individual and community level awareness and involvement. Moreover, it is agreed by many that nature restoration and reforestation improve the quality of life and fight climate change and global warming; whilst at the same time allowing social and economic development.

Although the targeted group's responses reflected that, they prefer none arid nature, their responses towards nature and biodiversity conservation state that they care and would like to participate in conservation initiatives, which assures the importance of awareness programs in arid regions for young individuals.

Conclusion

The study resulted in a conclusion on which forms of nature people prefer and use, and what is accepted, tolerated, or rejected. The survey questions illustrated the common understanding people have of nature, and how they perceive nature in arid regions. The young urban dwellers are mostly attracted to forms they miss in their surroundings; nature according to their perspective is associated with greenery and plants that grow in humid regions rather than arid ones. Furthermore, images of the most seen species illustrated the arid regions resident's choices on what to plant in their surroundings, the flora selection is associated with the gained benefits, aesthetic value, and religious and cultural factors, as shown when selecting the olives trees as the most seen tree in the participant's surroundings. Despite the arid conditions and lack of water availability, many participants are attracted to non-native plants that consume high amounts of water, and people tend to irrigate their plants regularly. Moreover, the survey illustrated that more than 82% of the participants prefer pristine landscapes outside the city context more than designed ones.

Nature is argued as the original ecosystem's natural state within a region; accordingly, naturalness in arid regions imposes planting the region's native plants that suit water scarcity in arid conditions. On the other hand, nature integration within cities improves residents' quality of life. Yet, activities on the governance and decision-making level should be initiated to regulate vegetation selection methods for both public and private spaces; the activities include creating policies and standards to allow the proper processes and actions while imposing regulations to organize the planning and development in urban areas to increase the integration of nature according to each plot area. Moreover, awareness programs help to spread environmental education in schools, and universities to increase social responsibility on the individual and local community levels. These initiatives allow protecting and conserving natural resources and protecting biodiversity in arid regions.

The effect of rapid population increases urban sprawl and threatens native nature, protections programs should be initiated to control the sprawl and regulate urban development without affecting native species negatively. Finally, governments should increase native nature integration and protection, and familiarize communities with proper nature integration and restoration activities.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Appendix

Appendix 1. ANOVA result for the accommodation of young people and their selection of nature.

Place of Residence / Which one represents nature	City	Countryside	Desert area	Df	F	Sig
Wild native plants	2.92^{ab}	3.13^{b}	3.46^{a}	382,2	5.12	0.00
Densely built-up city center	2.87^{ab}	3.05^{c}	2.80^{d}	382,2	4.78	0.00
Waters in a mountain creek	3.11^{a}	3.65^{c}	3.79^{c}	382,2	6.38	0.00
Native vegetation in flowering aspect in spring	3.53^{ab}	3.04^{c}	3.39^{d}	382,2	6.20	0.00
Native vegetation in the dry season	2.21^{ad}	3.08	3.11^{ab}	382,2	4.00	0.00
Designed irrigated green in an urban park	3.10^{ad}	3.46^{c}	3.03^{d}	382,2	5.74	0.00
A spider	2.79^{cd}	3.13^{bd}	3.47^{d}	382,2	4.31	0.00
Sandy desert	3.61^{a}	3.14^{bc}	2.71^{b}	382,2	5.00	0.00
Arid mountains (accessible by infrastructure)	2.78^{ac}	3.69^{c}	3.40^{cd}	382,2	4.10	0.00
Lake with surrounding forest (non-arid region)	3.89^{d}	3.53^{c}	3.71^{b}	382,2	9.76	0.00
Native coniferous forests in semi-arid region	3.72^{b}	3.18^{a}	3.33^{cd}	382,2	8.83	0.00
A snake	2.45^{cd}	2.99^{d}	3.16^{b}	382,2	4.05	0.00
Urban residential neighborhood with street trees (low building density)	3.18^{d}	2.87^{b}	3.21^{ab}	382,2	3.85	0.00
Cactus plant	3.26^{ab}	3.07^{d}	3.56^{a}	382,2	6.12	0.00

Source: Authors

Appendix 2. ANOVA result for the accommodation of young people and participation in vegetation conservation (by irrigation).

	Where to live / Irrigation in the urban surroundings	City	Countryside	Desert area	Df	F	Sig
YES	Every day	3.61^{b}	3.87^{bd}	1.68^{a}	382,2	3.32	0.00
	Twice a week	2.79^{ab}	3.65^{c}	2.80^{d}	382,2	5.82	0.00
	Once a week	3.80^{a}	3.51^{c}	3.03^{b}	382,2	3.28	0.00
	Rarely	3.54^{b}	3.33^{d}	3.11^{cd}	382,2	2.65	0.00
NO IDEA	We don't have a house garden or trees on my street	3.08^{ab}	3.54^{c}	3.78^{d}	382,2	4.87	0.00
NO	The Plants rely on rain season	2.95^{d}	3.53^{c}	3.71^{b}	382,2	2.43	0.00

Source: Authors

Appendix 3. ANOVA result for accommodation of young people and their preferred of outdoor quality in the surrounding.

Where to live preferred outdoor quality in the surrounding	City	Country side	Desert area	Df	F	Sig
Forests with native plants and animals	3.87^{b}	3.21^{bd}	3.46^{b}	382,2	5.45	0.00
Designed landscapes, gardens with non-native plants	3.34^{ab}	3.10^{c}	2.80^{d}	382,2	5.06	0.00
Shopping centers, malls and city recreational facilities	3.11^{a}	3.25^{c}	3.18^{c}	382,2	4.21	0.00

Source: Authors

Appendix 4. ANOVA result for preferred outdoor activities and their preferred of outdoor quality in the surrounding.

Preferred outdoor activities / Preferred outdoor quality in the surrounding	Picnics	Jogging, walking, and cycling	Driving along with the car and watching surrounding	Df	F	Sig
Forests with native plants and animals	3.79[b]	3.21[bd]	2.19[b]	382.2	7.02	0.00
Designed landscapes, gardens with non-native plants	3.41[ab]	4.23[c]	3.14[d]	382.2	5.66	0.00
Shopping centers, malls and city recreational facilities	1.54[a]	3.67[c]	3.91[c]	382.2	4.67	0.00

Source: Authors

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Multifaceted analytical flood risk assessment in major tributaries-river benue basin-Taraba State, Nigeria

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Tracking the changes in the river basin system and identifying areas susceptible to flood disasters is an inclusive step in flood hazard control and management. This research analyzed the spatial variability of rainfall and physiographical attributes of the main tributaries of River Benue in Taraba with the aim of identifying areas susceptible to flooding on the basins. The spatial data subjected to WLC approach for reclassification were annual rainfall, digital elevation model, basin slope, land use, soil types, drainage density, and catchment area. The clincher to flooding in the state favors land use. The composite map of flood vulnerability revealed that vulnerable areas occupied 48.6% while highly vulnerable occupied 0.9% of the entire study area of 44,359.2 km^2. In terms of the area extent, the highly vulnerable region covers 410.6 km^2; the vulnerable area covers 21,576.6 km^2, and the areas that are not vulnerable cover 64.9 km^2. The towns that are at risk of a high vulnerability to flooding within the study area are Karim Lamido, Gassol, Ibi, Lau, Donga, Wukari, parts of Takum, Ardo Kola, Kurmi, Bali, and Jalingo. It was recommended among others that as the region's status is vulnerable to climate change and that this has a strong association with land use and land cover change, development along the floodplain should be discontinued.

Key words: Flood vulnerability; land use change; river catchment area; rank-sum method; river Lamurde, Taraba and Donga.

INTRODUCTION

Across the globe, floods pose remarkable stress on people's lives and properties. In flood-prone areas, flood risk and vulnerability are increasing due to changes in rainfall patterns, increased frequency of extreme events, and changes in land use and development as a result of socio-economic demand (Monica et al., 2016). The frequency is on the rise. This is not unconnected to the progressive deterioration of the basins, riverbeds, and streams, the blockage of natural drainages restraining the marshes, the increase of erosive processes by deforestation, and the exploitation of margins of rivers. Knowledge of the cumulative impacts of climate change at the sub-national and national levels is on the increase, hence the need for regular monitoring and

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assessment of the environment. Tracking the changes in river regimes and the capability to forecast flood disasters is an inclusive step in flood hazard control and vulnerability.

Although flooding is a natural occurrence, man-made changes to the land can also be an element. Development does not cause flooding but can aggravate the process of flooding. In cities and suburbs, pavement and rooftops prevent some rainfall from being absorbed by the soil. An encroachment through development in the path of geophysical agents is a factor. These can increase the amount of runoff flowing into downstream catchments. There exists a noticeable relationship between land use change, slope/aspect, soil moisture, stream network, basin catchment size, rainfall amount/ intensity, and flood vulnerability of a place.

Comprehensive mitigation of the effects of flood entails certifying that all vulnerable places are identified and adequate safety measures are taken to ensure adequate preparedness, effective response, quick recovery, and effective prevention (Suleiman et al., 2014). Relevant information on the disaster-prone area like elevation, slope aspects, soil types, the proximity of built-up areas to drainages, the network of drains, the presence of buffers, and extent of inundation, cultural practices as well as attitudes and perceptions of disaster are needed to provide an effective response to flood disaster. This information can be analyzed and their various contributions to hazards identified in GIS environment using multi-criteria analysis.

The study that spelled out the flood risk zones of the study area using GIS platform like this is not on the world digital board, it is against this backdrop that this project aims to generate a composite flood vulnerability map of the river Lamurde, Taraba, and Donga for decision makers by mapping the potential sources of flooding. This research spelled out the percentage contribution of climatologic and physiographical attributes of the basin to flooding in the catchments area of Taraba, especially along the major tributaries of river Benue in the state.

LITERATURE REVIEW

The hydro-metrological disasters around the globe are on the increase (Okada and Odhiambo, 2019) and several factors have been adduced as the causative agents. These include, increase in rainfall, land use change among others.

Oruonye (2015) in his assessment of the impact of land use changes along the floodplain of river Lamurde found out that land use along the plain has undergone a substantial level of change from open fields and shallow lands to intensively cultivated irrigation and residential areas. He noted that excessive water abstraction, deforestation for fuel wood and other domestic uses, excessive use of chemical fertilizers, and land degradation due to improper agricultural practices are the order of the day. Suleiman et al. (2014) in their research work on flood risk and vulnerability mapping for disaster management at Lokoja, Kogi State, Nigeria have submitted that administrative and commercial area like that of Lokoja serves as a ‘gateway’ settlement and as such serve as both a resort and stop over settlement for most travelers and business people. According to them, this is resulting in increased physical planning problems as buildings are constructed on every available space including the marginal flood plains and river banks. This has been noted to have a gross implication on the river regime and vulnerability of the place.

Several factors accrued to form the basis of incessant flooding in Jibia in Kastina. The orientation of the basin and the closeness of the farm lands on one hand, and the diversion of the Dan Marke stream. According to Asemota (2018), the diversion of the stream which had not been dredged since its construction in 1991 means that the stream could not flow along its natural courses which later became built up with houses. Natural and anthropogenic-induced disasters are indisputably increasing due to numerous factors such as urbanization, population growth, infringing on the floodplain, and climate change. Flood disasters not only cause huge losses of human life but also can result in several economic losses when community dwellers placed themselves in the path of geophysical agents through encroachment.

The multi-criteria analysis (MCA) has been widely applied to solve a broad range of multi-criteria decision-making and address flood risk challenges all over the globe (Cozannet et al., 2013). Outside the nation many studies using MCA are on the world digital board. Ouma and Tateishi (2014) applied MCA in order to analyze the flood vulnerable areas in Turkey and Kenya. Kazakis et al., (2015) applied GIS-based multicriteria flood risk assessment in the Greater Athens area and the Rhodope–Evros region, Greece. GIS and remote sensing can be used to address flood losses through a number of applications.

Study objectives

The aim of this research is to generate a composite flood vulnerability map of the river Lamurde, Taraba, and Donga for relevant decision-makers in the state. Three specific objects are to:

i. Identify causes of flooding in the catchment area of major tributaries of river Benue in Taraba State
ii. Determine the percentage contribution of climatologic and physiographical attributes of the basin to flooding in the catchments area of Taraba

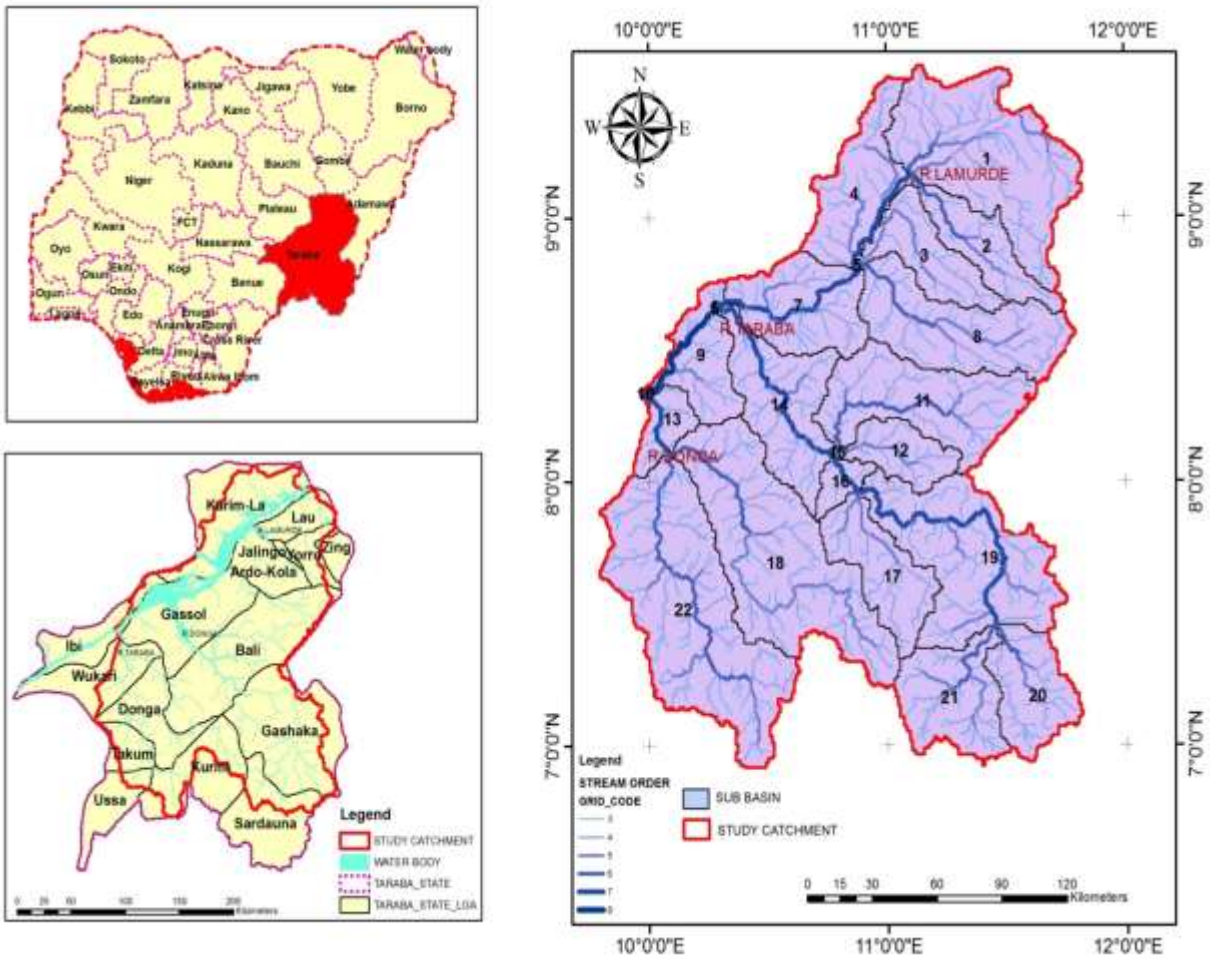

Figure 1. Catchment and drainage pattern of the study area.
Source: Taraba State Ministry of Land and Survey, (2021)

iii. Develop a flood susceptibility map of the study area

MATERIALS AND METHODS

Description-study area

The study area is the three major tributaries of river Benue in Taraba State. The terrain is located in the northeastern part of Nigeria. It lies between latitude 6° 46' and 9° 45' North of the equator and between longitude 9° 25' and 11° 50' East of the Greenwich Meridian (Figure 1). Roughly twenty-two sub-basins are identifiable in the study area. These sub-basins network with these three major rivers and drained a total area of about 44359.2 km^2 having a perimeter of about 1521.6 km. The land area has three main tributaries to River Benue: River Lamurde, River Taraba, and River Donga.

River Lamurde drains only one watershed. River Donga conspicuously drains twelve sub-basins. River Taraba as it transverses from the upland to the downstream of the study area, westward drains nine catchments. The study area is characterized by a tropical continental climate marked by dry and rainy seasons. Commencement of rainfall is around April-May and this ends around September-October. The annual mean is less than 1000 mm in latitude 9^0 (Adebayo, 2002), and 1350 mm of rainfall has been documented in the Southern part of the State. This typically results in an increase in rainfall on the crest and to the windward and a rain shadow to the leeward side (Bawden and Tuley, 1966).

The study area's temperature varies from month to month and from place to place reaching the peak at the end of the dry season (Match). Maximum temperature ranges between 26°C to 39°C while minimum temperature ranges between 15 and 18°C. The relief of the study area can be conveniently subdivided into two broad groups-highland and lowland. The highland area consists of the Shebshi Mountain in the northeastern part of the region. Towards the western part of the region is the extensive undulating lowland which forms part of the eastern Muri plains (Oruonye, 2011). River types vary across the state and are often a product of geology, slope, and human intervention. Oruonye (2011) has observed that the northern bank of the river has heavily encroached on occupants irrespective of the devastating effects of recent floods in the area while the southern parts are notably exploited. The vegetation type of the study area has been adversely affected by human activities leading to the clear-cutting of trees in many parts of the area. Artificial vegetation and a few economic trees have replaced natural

vegetation especially as we transverse the northern part of the study area. Considering the management and harnessing of natural resources in any area especially water and land resources, the population is a strong factor. The rapid growth of the study area has necessitated the expansion of the settlement and infrastructures to accommodate relative increases in population (Oruonye, 2015). Farming is the main occupation of nearly three-quarters of the people's population while only ¼ is involved in other vocations. This is so because of the vast expanse of arable land. Also, high water resources in Jalingo town offer great potential for irrigation, especially using simple and inexpensive technologies. To curb this menace of total dependence on rainfall which poses grievous set back on agricultural productivity, especially in the northern part of the state, there are those farmers who exploit the plains of the river Benue in the State (Orunoye, 2011). Among the three tributaries of river Benue in Taraba, river Lamurde is the most exploited. The construction of new roads and bridges along river Lamurde and river Mayogwai, its tributaries, plays a very significant role in opening up large areas for the construction of residential houses and intensification of agricultural activities along the river banks. These changes in uses along the banks of the Lamurde River have resulted in a large-scale transformation of the landscape. This as expected has serious implications for the river regime.

Methodology

The data used for this research include Satellite imagery (Enhanced Thematic Mapper (ETM) and Topographic maps. A set of causative factors concerning the mostly hydrological, geological, and physio-geographical characteristics of the study area that can be measured and evaluated were considered for the analysis (Zeleňáková, et.al, 2015). These include: (1) Rainfall (2) Elevation (3) Land use (4) Drainage Density (5) Basin slope (6) Soil types (7) Catchment area.

Rainfall generation data and processing

The spatial distribution of the rainfall intensity was performed. The data were then rasterized and assigned classes. From this raster data, Mean Annual Rainfall (MAR) was generated for the three catchments. This serves as the Z value for interpolation in the Inverse Distance Weighted tool to create the rainfall map of the study area Figure 2. Rainfall data were divided into four classes. In the classification process, an area with higher rainfall is assumed to be very highly affected by flood and then ranked as class 4, which is between (1801.9-2102.2) mm/year. Following the very high hazard class, there is a class high (1501.6-1801.9 mm/year) ranked as class 3, moderate (1201.2-1501.6 mm/year) ranked as class 2, low (900.9-1201.4 mm/year) ranked as class 1.

Elevation generation and slope map

The Elevation and slope map of the study area was extracted from SRTMDEM. The elevation data values were then subdivided into four classes. Categorization was based on the surface topography of the terrain. Thus:

(i)The basin valley which is found along the tributaries with heights between 92 and 323 m above the sea level was classified as "highly vulnerable" to flood.
(ii) The plain with heights ranging from 323 to 646m above sea level was classified as "vulnerable" to flood.
(iii) The upland areas with a range of 645 to 1122m above sea level were classified as "marginally vulnerable".
(iv)The high land areas with heights range of 1122 to 2244m above sea level as "not vulnerable".
The slope map was prepared in percent grade using the DEM of the study area. The district's values were subdivided into four classes.

Generation of land use types and processing

Landsat 8 was geo-referenced to the Universal Transverse Mercator (UTM, zone 32° N) Minna datum. A supervised image classification technique was employed in this study. The training site was chosen to represent land use classes such as vegetation, built-up area, bare land, and water body. Classifications were limited to these variables because these are known linkages to the flood hazards of an area. The data were divided into four classes.

Generation of drainage map and processing

Drainage is an essential factor of consideration when an assessment of an area for flood hazard vulnerability is a concern. The drainage map was derived from the DEM. The drainage density was reclassified and their sizes were subsequently identified in Arc GIS into four classes.

Generation of soil types and processing

Soil type was obtained from Worldmap.havard.edu/data/geonade: DSMW_RdY (2015). Reclassification into four classes was on the basis of the content of clay particles. The soil type that has a very high capacity to generate a very high flood rate was ranked as ″class 4″, the soil type with a high capacity to generate high flood was ranked as ″class 3″, soil type with a moderate capacity to generate moderate flood was ranked as ″class 2″, soil type with low capacity to generate low flood was ranked as ″class 1″. This was divided on the basis of the content of clay particles into four classes.

The catchment area

The river basin area was divided into sub-catchments and their size was subsequently identified in Arc GIS. Sub-basins were divided into four classes.

Physiographical factors contribution to flood hazard potential

The straight ranking was used to identify factor's classes, with the most endemic for flood occurrence= 1, next risk = 2, etc (Zeleňáková et al., 2015). The conceptual framework for data processing using MCA in GIS is presented in Figure 2.

To generate factor values for each evaluation unit, each factor was weighted according to the estimated significance for causing flooding. The purpose of criterion weighing is to express the importance of each factor relative to other factors.

To obtain numerical weights from this rank order for this research, the researcher adopted the formula provided by Yahaya et al. (2010) see Eq 1. Normalized weights of the criterion were calculated using the equation (Equation 1).

$$Wj = \frac{n - rj + 1}{\Sigma(n - r\kappa + 1)} \quad (1)$$

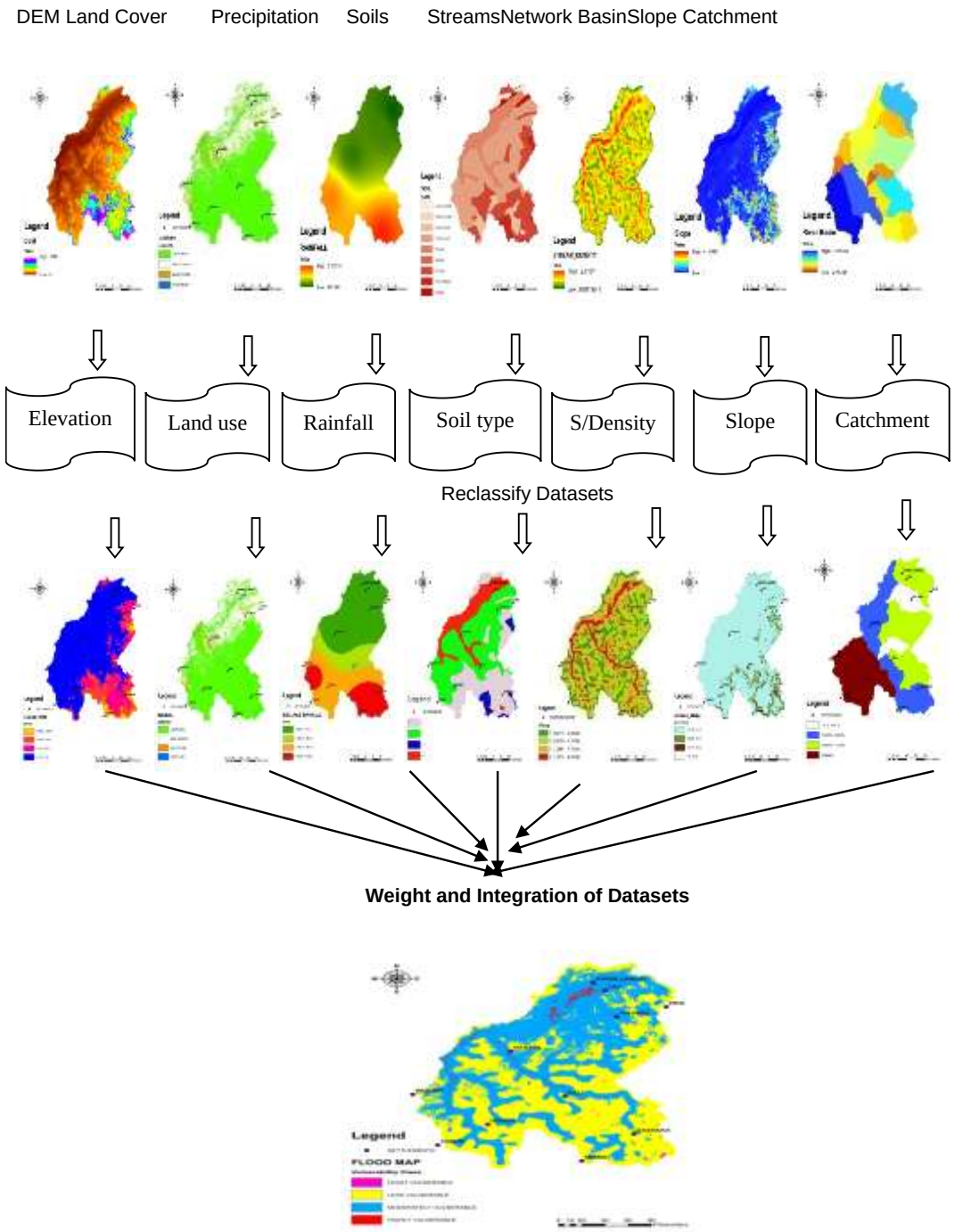

Figure 2. Framework for data processing flow chart in geographical information system.
Source: Suleiman et al, (2014)

Where: W_j is the normalized weight of each factor; n is the number of factors under consideration (k = 1, 2, 3…n). For this study n = 7 r_j is the rank position of the factor.

Each factor is weighted by Equation 2.

$$W_j = n - rj + 1 \quad (2)$$

and then normalized by the sum of weights using (Equation 3)

$$\sum(n - r_k + 1) \quad (3)$$

The purpose of criterion weighting is to express the importance of each factor relative to other factors (Table 1). More important factors have a greater weight in the overall evaluation (Yalcin et al., 2004).

To obtain the final composite vulnerability index, these sub-

Table 1. Weight assessment by ranking method.

Factor	Rank	Assigned weight	Weight %
Rainfall	1	0.25	25
Elevation	2	0.2142	21
Land use	3	0.1785	18
Stream order density	4	0.142	14
Slope	5	0.1071	11
Soil	6	0.0714	7
Basin	7	0.03571	4
Sum		1.00	100

Source: Authors

indices were combined using the additive (averaging) approach. Thus:

$$H = \Sigma (F_1 * W_{J1} + F_2 * W_{J2} \ldots\ldots\ldots\ldots F_7 * W_{J7}) \quad (4)$$

Where: H= Resulting flood hazard; F_1, F_2…. F_7 are respective factors; W_{J1}, W_{J2}……. $W_{J7}$are the normalized weights for each factor.

RESULTS AND DISCUSSION

This part of the study presents the results of the analyses of the climatic and physiographical factors that contribute to flooding hazard potential in the study area.

Spatial rainfall variability in the catchments area

The results show evidence of a progressive decrease in rainfall from the southern region up to the northern region of the state. This result affirms the submission of Adebayo (2002). Their work on rainfall variation, water resources potential, and implication for flooding in the state, typifies a decrease of rainfall northwards. According to them, daily rainfall at Gembu, river Taraba (Gassol station), river Donga (Donga station), and river Lamurde (Jalingo stations) stood at 220.8 mm, 162.0 mm, 174.0 mm, and 142.9 mm and they all occurred on Month of August. The analysis added that the highest annual rainfall event ever recorded over the period under study was in Gembu and the least from Jalingo (river Lamurde) (Adelalu et al, 2018). In the state, annual rainfall decreases with increasing latitude (Adebayo, 2002).

Elevation range in catchments area

From the analyzed DEM, 11% of the land surface area lies between 92 to 323m, 15% lies between 323 to 645 m, 22% lies between 645 to 1122m, and 52% of the land surface in the study area lies between 1122 to 2244m (Table 2).

Land use and land cover types of the study catchments

From Table 3a to c, the three catchments show natural vegetation cover of about 14,229 km^2. This account for 50.1% of the land mass of the catchment area under study. Cultivated area and the bare land in the region amount to about 13,146 km^2. This accounts for about 46% of the basin area. The built-up area covers about 807 km^2, occupying just 3%.

Stream order density in the catchment area

The automated generated tributaries show 22 sub-basins in the study area. River Lamurde has a lone catchment area. River Taraba has 10 sub-basins while there exist 4 sub-basins in the river Donga catchment area. This implies that there are about 7 other minor basins in the study area outside the studied river catchments. River Lamurde with a 1,264 km^2 basin area has 9 stream orders while river Taraba with a basin area of 15,777 km^2 and river Donga with a basin area of 11,355 km^2 have 7 each. The result from the slope analysis is indicated in Table 4.

Soil types - study area

There exist nine groups of soil types in the study area. Vertisols and fluvisols mostly along the river basin are assumed to have a very high flooding capacity ″class 4″, Luvisols were next assigned as high ″class 3″, Nitisols were assigned as moderate class 2, Acrisols/Leptosols/ Arenosols/Lithosols are assigned as a low ″class 1″

Table 2. Relief classification along the study areas.

Relief classification	Elevation range (m)	Land area (km^2)	Percent
Flood plain	92-323	4.761	11
High flood plain	323-645	6.637	15
The lowland	645-1122	9.832	22
The highland	1122-2244	23.127	52
Total		44.359	100

Source: Authors

Table 3a. Land Use Types and percentage covered in River Lamurde catchment area.

River Lamurde catchments		
Type	**Area (km^2)**	**Percent**
Vegetation	567	44
Bare land	577	46
Built up area	114	9
Water body	6	1
Total	1,265	100

Source: Authors

Table 3b. Land use types and percentage covered in River Taraba catchment area.

River Taraba catchments		
Type	**Area (km^2)**	**Percent**
Vegetation	8.330	53
Bare land	6.863	43
Built up area	442	3
Water body	142	1
Total	15.777	100

Source: Authors

Table 3c. Land use types and percentage covered in River Donga catchment area.

River Donga catchments		
Type	**Area (km^2)**	**Percent**
Vegetation	5.332	47
Bare land	5.705	50
Built up area	251	2
Water body	65	1
Total	11.355	100

Source: Authors

and as such have a low flooding capacity.

Table 5a to c shows the soil types and percentage covered in river Lamurde catchment area.

Flood susceptibility map - Taraba State

Figure 3 reveals the vulnerability map of the catchment area. The result shows four classes for the whole study area. These classes include highly vulnerable, (deep blue color) vulnerable, (blue color) marginally vulnerable, (yellow color), and not vulnerable, (brown color). The not-vulnerable class occupied an area of about 0.1%, the marginally vulnerable area occupied 50.3%, and the vulnerable area occupied 48.6%, and the highly vulnerable occupied 0.9% of the entire study area of 44,359.2 km^2. In terms of the area extent, the highly vulnerable portion covers 410.7 km^2 vulnerable portion covers 21,576.7 km^2; the marginally vulnerable portion covers 22,306.9 km^2, and the area that is not vulnerable covers just 64.9 km^2.

Flood vulnerability potential in Taraba State

Rainfall and effect on flooding

It is no longer in doubt that climate change has led to changes in the known patterns of rainfall and other climatic variables as well as increased the frequency and magnitude of natural disasters including floods in different parts of the world. Flood is indeed a global environmental issue that had destroyed lives and property amidst other untold hardships (Rhoda et al., 2017). The establishment of climate change in the study area is no news either (Adebayo, 2012).

Likewise, it is evident that rainfall decreases as we progress northwards while the flooding activities take the reverse case (Figure 3). River Lamurde which is in the northern parts of the three studied rivers is the most vulnerable. Flood is arguably the most common and severe natural disaster in the Taraba especially Jalingo environment along river Lamurde. It has become an annual environmental problem during every rainy season. Umar et al. (2015) have noted that in most parts of the Sudano-Sahelian region of Nigeria, the months of August

Table 4. Slope categories and the communities in the study area.

Slope (degree)	Land area (%)	Slope class	Communities identified
0-10.4	18	Gentle slope	Gassol, Ibi, Donga, Wukari, parts of Takum, Ardo Kola, Kurmi, Bali and Jalingo
10.4-20.8	16	Moderate steep	Northern Karim Lamido, Western area of Bali, and Kurmi
20.8-31.3	19	Less steep	Serti in Ghashka, Northern Bali, and Northern Ghasaka
31.3-41.8	47	Steep slope	Takum, Gembu and Gashaka

Source: Authors

Table 5a. Soil types and percentage covered in River Lamurde catchment area.

River Lamurde		
Soil type	**Area (km^2)**	**Percent**
Ferric luvisol	7.211	57
Fluvisols	776	6
Lithosols	3.890	31
'Numic nitosols'	769	6
Total	12.645	100

Source: Base on Soil Worldmap.havard.edu/data/geonade: DSMW_RdY (2015)

Table 5b. Soil type and percentage covered in River Taraba catchment area.

River Taraba		
Soil type	**Area (km^2)**	**Percent**
Dystric fluvisols	88	1
Ferric acrisols	1.169	7
Ferric luvisol	6.750	42
Fluvisols	1.185	8
Lithosols	5.549	35
Numic nitosols	1.036	7
Total	15.777	100

Source: Base on Soil Worldmap.havard.edu/data/geonade: DSMW_RdY (2015)

Table 5c. Soil type and percentage covered in River Donga catchment area.

River Donga		
Soil type	**Area (km^2)**	**Percent**
Ferric acrisols	1.378	12
Ferric luvisol	6.097	54
Fluvisols	672	6
Lithosols	3.023	26
'Numic nitosols'	185	2
Total	11.355	100

Source: Base on Soil Worldmap.havard.edu/data/geonade: DSMW_RdY (2015)

still remained the rainiest month and that most seasonal floods in the region are likely to occur in the month of August or September. This is also very true in the study area because past records of farm flush, building, and bridge collapse had been in the month of August or September. Although there were notable drastic fluctuations in annual rainfall total from year to year, there has not been a significant increase in annual rainfall total in these areas except at the Upstream-Gembu (Adebayo, 2012). The study area's- upland catchment, Gembu, has been witnessing an upward trend in rainfall total (Adebayo, 2012). However, the study area's down streams catchments around Lamurde, Gassol, Donga, have comparatively lower rainfall but there is still a real concern for flooding, especially in the river Lamurde area where there are generally more densely cultivated and populated.

In this research, MCA shows a false representation of the observable pattern of flooding reality in the study area until relief and land use were introduced into the model developed for the assessment of the contributing factors. This conclusion is supported by the recent work of Gelleh et al. (2016), where the author found that land use and relief contributed more to flooding than other factors considered in the model. However, Eguaroje, et al. (2015) admitted that among the causative factors of flooding in Oyo state, rainfall top the list. In Uyo, rainfall intensity, land use, and elevation of an area are strong factors (Saturday et al., 2021). In the study area, however, land use tops the list.

Land use and effect on flooding

The three catchments show natural vegetation cover of about 14229.8 ha which is about 50.1% of the land mass of the catchment area under study. Cultivated area and the bare land amount to about 13146.2 ha which is about 46.3% of the basin area. Built up area is about 806.9 ha which is just about 2.8% is. With a record of vegetation cover, which is more than 50% of the basin area, there will be an expectedly high rate of infiltration. High infiltration suggests low runoff. This provides support evidence of low flooding in some areas and high flooding in some areas that are highly stripped of vegetation. The

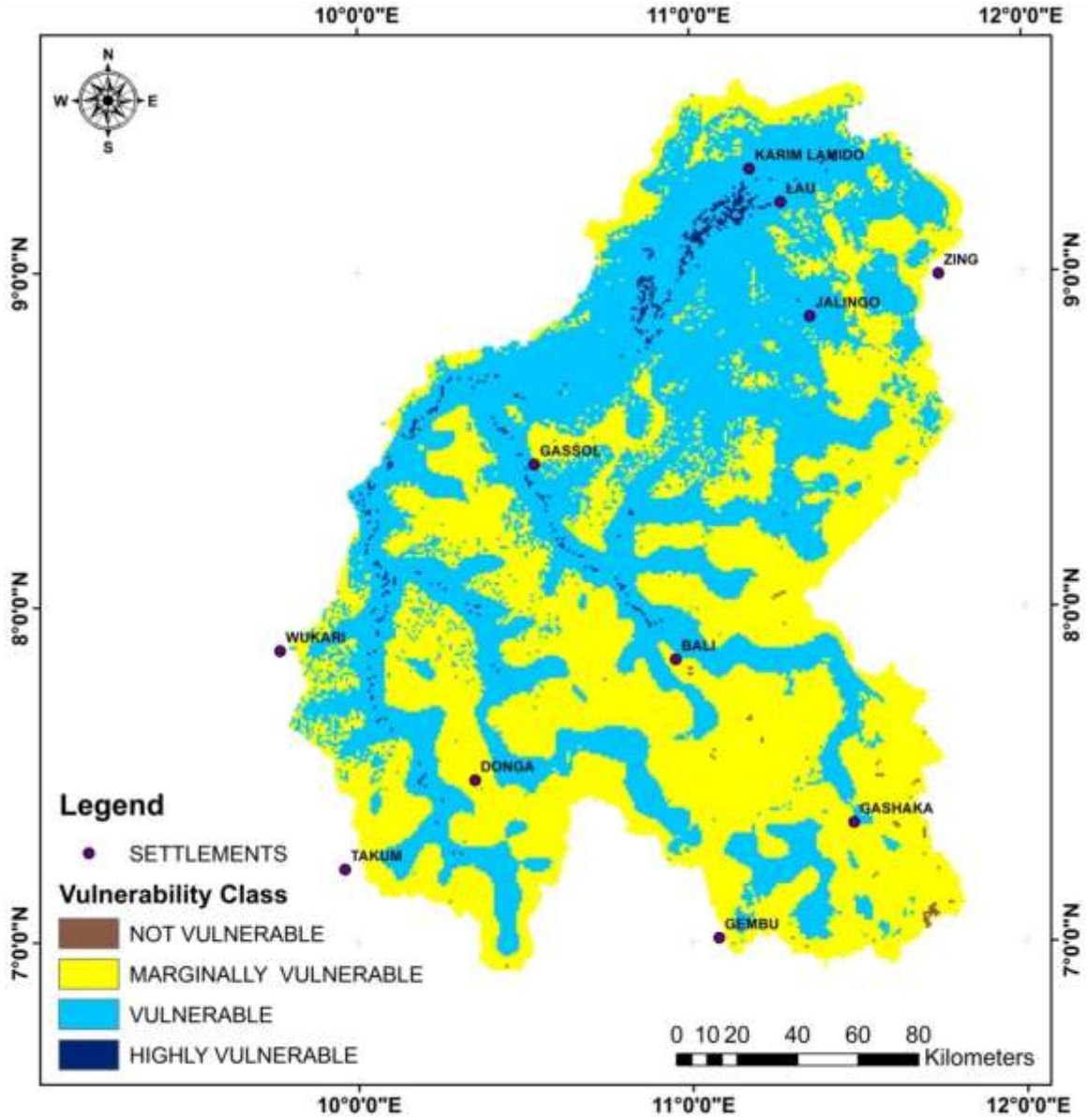

Figure 3. Flood vulnerability map of the study area.
Source: Authors

vulnerability of the study area to flooding seems strongly linked to anthropogenic activities. The extent of built-up or encroachment to the plain, the transformation of the terrain through lumbering and deforestation, displace vegetation, which hampers the free flow of water (Kelemen and Blist'anova, 2014) hence flooding. However, it can be said of the study area the transformation is concentrated in the flood plain. As the rainfall shortens (Adebayo, 2012) it pushes the farming stakeholders to the plain thereby increasing their vulnerability. This implies flood hazards in the study area can be averted since it is not majorly based in nature.

Conclusion

This study assessed seven geo-spatial elements in order to determine their influence on flood vulnerability potentials in catchment areas of river Lamurde, river Taraba, and river Donga in Taraba State. The influence of each element was examined step by step by introducing them one after the other in the MCA model.

The composite map of flood vulnerability of the study using weighted overlay analysis in a GIS environment revealed that not vulnerable class occupied an area of about 0.1%, the marginally vulnerable area occupied

50.3%, and the vulnerable area occupied 48.6% while highly vulnerable occupied 0.9% of the entire study area of 44,359.2 km^2. In terms of the area extent, the highly vulnerable portion covers 410.6 km^2, the vulnerable portion covers 21,576.6 km^2, and marginally vulnerable portion covers 22,306.8$km^{2,}$ and the area that is not vulnerable covers 64.9 km^2. The towns that are at risk of a high vulnerability to flooding within the study area are Karim Lamido, Gassol, Ibi, Lau, Donga, Wukari, parts of Takum, Ardo Kola, Kurmi, Bali, and Jalingo. These towns are at high risk of flooding mainly because of their change in land use and relative position. These towns occupy the downstream section of the study area. This supports the fact that the relief of an area plays a very significant role in the occurrence of flood disasters in a particular area. The southeastern part of the area has a relatively high elevation which gradually progresses towards the southwestern part of the area. This spatial pattern proves why highly prone areas to flood are more pronounced in the southwestern part of the state and also towards the northwest. An area with minimal flood risk occupies 50.3% of the total land mass. About 22306.8 km^2 in area extent and the local governments under this region include Northern Karim Lamido, the Western area of Bali, Kurmi, and Yorro. Others on the list are Ussa, Serti in Ghashaka, and Northern Bali. Only 0.1 % of the study area is at the safety of flood hazards. The area extent of the region covers 64.9km^2. The LGAs that fall into this category are Takum, Gembu, and Gashaka.

Recommendations

It is true that the region's status is vulnerable to climate change. However, the vulnerability has no doubt an alliance with the land use and land cover change. Therefore, there is a need for farmers to adopt the 'farm forest' method of the farming system. This will check the adverse effects of flooding and serve as a windbreak and source of additional revenue apart from adding nutrients to the soil. Yearly flooding and the consequent losses of lives and properties in the state are avoidable errors. So, the laws of the land governing siting of residential or industrial buildings must be duly respected. Drains in the towns should be free of debris to allow the free flow of overflow orchestrated during the peak of the rainy season especially the month of September. The people of Karim Lamido, Gassol, Ibi, Lau, Donga, Wukari, parts of Takum, Ardo Kola, Kurmi, Bali, and Jalingo should be enlightened through both electronic and social media to henceforth desist from erecting any form of structure or residential buildings along areas that are waterways to avoid the incidence of flooding.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Optimal extraction process of flavonoids from *Suaeda salsa* by response surface methodology

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***Suaeda salsa* is a genus of *Salicaria* in the Chenopodiaceae family. *S. salsa* is mainly distributed in coastal areas, growing in saline-alkali soil. Flavonoids are found in Salicyphala salicyphala and have various functions, such as lowering blood glucose, resisting mutagenesis and improving immunity. It was found that flavonoids also had antioxidant effects, and the study of antioxidant activity of flavonoids became the focus. In this paper, the flavonoids were extracted from the halophytic plant *S. salsa* by 60% ethanol extraction method, and the antioxidant activity was compared with ascorbic acid (VC) solution. To optimize the ethanol extraction process of flavonoids from *S. salsa*, factors of extraction time, extraction temperature, and liquid-solid ratio on the mass of flavonoids derived from *S. salsa* were investigated to seek the optimal extraction conditions. The results showed that the optimal extraction conditions were as follows: extraction time 58.63 min, extraction temperature 52.08°C, solid-liquid ratio 1:21.33 g/mL. Under these conditions, the extraction mass of flavonoids reached 6.40 mg/g. When the concentration of flavonoids was 1.5 g/L, the hydroxyl radical removal rate reached the maximum (54.94%). At the same time, the extraction process of flavonoids from *Suaeda salicata* optimized by response surface analysis is also reasonable and feasible.**

Key words: *Suaeda salsa*, flavonoids, response surface methodology, optimization.

INTRODUCTION

Suaeda salsa is an annual herb, widely distributed in Europe and Asia (Qu et al., 2019). And the same time, it is grown in a lot of areas in China such as Hebei, Hainan, Shandong and so on. According to statistics data, the annual output of *Suaeda salsa* from the Yellow River delta reaches 3.3×10^5 t. The seeds of *Suaeda salsa* containing lots of unsaturated fatty acid have well edible value (Ji, 2015). The saline-alkali land contains a large number of inorganic ions (Ca, Fe, Mg), leading to the content of trace elements in *Suaeda salsa* being higher than other plants (Zhao et al., 2018). In addition, stems and leaves are also rich in amino acid, flavonoids, vitamins and minerals (Mohammed, 2020). With the expansion of saline-alkali land, the sustainable comprehensive utilization requires more attention. Flavonoids which widely exist in the roots, stems, leaves, flowers, and fruits of higher plants and ferns, is a natural organic substance with a variety of species and complex structure. The oxygen atoms in the first place of the molecules incorporated in a keto carbon base can form a salt with strong acid. Thus, it is also called flavin or flavone due to the yellow hydroxy derivatives including fat flavonoid, flavonols, isoflavones,

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flavanones, and chalones. Free radicals are the intermediate products of biochemical reactions in the process of human life activities. If the body produces too much or removal too slowly, it will cause damage to cells and organs. It is necessary to search for material with a good capturing ability to hydroxyl radicals. Among the reagents, flavonoids with a good capturing effect from *Suaeda salsa* are a very effective source (Husain et al., 1987; Oganesyan et al., 2001). The flavonoids promote the healthy functioning of people's system, such as strong antioxidation, anticancer, antitumor, anti-inflammatory, anti-cardiovascular disease, immune regulation, antibacterial, antiviral, hypoglycemic, and hypolipidemia (Husain et al., 1987; Flowers and Colmer 2008; Yi et al., 2017; Du and Zheng, 2018; Liu et al., 2019; Zhang et al., 2021a).

Response surface methodology is one of the quick and effective methods for acquiring the optimal conditions of experimental results (Bezerra et al., 2008; Xiong et al., 2015; Fabre et al., 2021; Zhang et al., 2021b). This method is used to analyze the planar response curve and apply it to study and solve various technical problems in data processing of nonlinear models. Its main functions include the process design for comprehensive tests, construction of test model, checking the compatibility of factors, and seek for the optimal horizontal combination response conditions. The simple quadratic regression equation with one variable demonstrates the relationship between the independent variable and the response value. During the process, every point of the experiments is conducted independently for continuous data. It is convenient and fast to acquire the horizontal regression fitting response of every related factor. A fast algorithm for contour linear graph and surface of the quasi-plane combination and horizontal response can be realized by the rapid regression of the results of the whole test process. However, the premise of the tool is that the designed experimental sites should include the best experimental conditions. If the experimental points are improperly selected, the optimization of response surface analysis cannot obtain the precise result. Therefore, reasonable experimental factors and levels should be confirmed before optimization.

In this paper, response surface methodology was used for the optimal extraction process of flavonoids from *Suaeda salsa*, providing the theoretical basis and technical support for further development and utilization of *Suaeda salsa* from saline-alkali land. Ethanol extraction can effectively avoid impurities such as polysaccharides, tannins, and pectin. The experiment was designed using ethanol as an extraction solvent by Design-Expert software. The oscillating temperature, reaction time, and the solid-liquid ratio were selected as variable and the mass of flavonoids extracted from *Suaeda salsa* was set as the response value. Then, the relationship between the independent variable and the response value was obtained. Finally, the optimal extraction conditions of flavonoids from *Suaeda salsa* were determined. Additionally, the capability of the capturing ·OH was determined in the simulated system of hydroxyl radical generated by Fe^{2+}-salicylic acid and H_2O_2.

MATERIALS AND METHODS

The seeds of *Suaeda salsa* were washed and dried in a vacuum oven at 60°C. Before screening through a 60 mesh sieve, the dried seed was ground into powder. Anhydrous ethanol was purchased from Beijing Jiaxing Chemical Glass Instrument Industry and Trade Co., Ltd. Petroleum ether was purchased from Shandong Century Tongda Chemical Co., Ltd. Sulfate-iron crystal was obtained from Beijing Fengling Chemical Reagent Technology Co., Ltd. Salicylic acid crystal was purchased from Beijing Northern Tianshand Chemical Reagent Factory. Hydrogen (30%) was provided by Tianjin Pufa Chemical Co., Ltd. Other agents used here are of AR grade as received.

Material pretreatment

After wash and dryness in the shade, seeds of *Suaeda salsa* were placed in a vacuum oven at 60°C. The dried seeds were pulverized into powder before sifting through a 60 mesh standard sieve. The petroleum ether was added to the powder to immerse and wash with a hot water bath for 1 h repeatedly. When the aforementioned resulting product was filtrated and dried with the addition of water, a natural alkaline *S. salsa* powder after oxidation skims can be prepared.

Extraction process of flavonoids

In the typical extraction process, 2 g *S. salsa* powder was transferred in a 50 mL conical flask with a certain solid-liquid ratio. Subsequently, the conical flask was placed in the water bath at a certain temperature and time with stirring speed of 300 r/min. Then, the product was recovered after duplicated suction filtration of the solid-liquid mixture. After three times wash, the combined filtrates were transferred in a 500 mL beaker and concentrated to one-third of their original volume at the temperature of 80°C in a water bath. Next, 4 times volume of water was added to the concentrated filtrate. The mixture was refrigerated and settled at 4°C for 2 h. At the end, the product was centrifuged in the centrifuge at the speed of 3000 r/min for 10 min. The insoluble material was collected in the evaporating dish, and the flavonoid powder was obtained ultimately.

Single factor experiment

According to the alcohol extraction-water precipitation method, flavonoids were separated from the powder of *Suaeda salsa* using anhydrous ethanol. In every single factor test, two of the variables were fixed and one was changed. Select the factors of extraction temperature, extraction temperature and the solid-liquid ratio as variables to study the optimized extraction process of flavonoids. During the single factor experiment, 10 g *Suaeda salsa* powder, 200 mL anhydrous ethanol, and 45 min reaction time were selected to investigate the effect of reaction temperature on extraction with the reaction time ranging from 15 to 90 min. Then, 10 g *S. salsa* powder, 200 mL anhydrous ethanol, and 45 min reaction time were selected to investigate the effect of reaction temperature on extraction with the reaction temperature ranging from 30 to 70°C. Finally, the liquid-solid ratio between the *Suaeda salsa* powder and

anhydrous ethanol was 1:10, 1:15, 1:20, 1:25, 1:30 and 1:35 g/mL when the oscillation temperature was set as 50°C and reaction time was selected as 45 min.

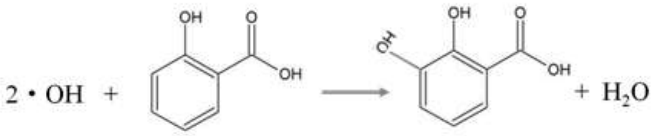
Response surface analysis

According to the single-factor experiment, extraction time, extraction temperature, and solid-liquid ratio three factors three-level experiment were determined. Experiment conditions were designed using the Design-Expert software (Bezerra et al., 2008). Mass of extraction flavonoids was selected as the response value and three factors three levels quadratic regression orthogonal combination test was conducted using the Box-behnken model (Lee et al., 2000; Maiti et al., 2020; Mona et al., 2011). A (extraction time), B (extraction temperature), and C (solid-liquid ratio) were defined as argument (X) and mass of extraction flavonoids was defined as response value (Y). Response surface analysis was performed three times in every group of experiments to acquire the average value.

Capturing effect of flavonoids on hydroxyl radicals

The capturing effect was conducted through a reaction between the hydroxyl group of flavonoid molecules and the hydroxyl radicals. The experiment was performed to construct a model of the reaction system on the basis of Fenton reaction. Though its good activity, the hydroxyl radicals produced by H_2O_2 and Fe^{2+} have a short existence time. The addition of salicylic acid which can produce colored substances, can effectively capture the hydroxyl group. The reaction is shown as follows:

$$H_2O_2 + Fe^{2+} \longrightarrow Fe^{3+} + \cdot OH + OH^-$$



The obtained colored substances have strong adsorption at 510 nm. When another measurable substance that can react with hydroxyl radicals was added to the solution, the color of substances grows weak because they can compete with salicylic acid. In the typical procedure, 1 mL H_2O_2 (9 mmol·L^{-1}) solution, 1 mL $FeSO_4$ (9 mmol·L^{-1}) solution, 1 mL of salicylic acid-trifluoroethanol solution (9 mmol· L^{-1}) and 1 mL of apparent oid solution were diluted to 10 ml and then added to 3.5 mL cuvette in turn. Finally, the absorption value was measured at 510 nm. Each group of experiments was repeated 3 times, and the average was taken into the following equation.

$$\text{Removal rate}(\%) = 1 - \frac{A^{sample} - A^{control}}{A^{reference}} \times 100$$

The control group used distilled water replace H_2O_2 solution and the blank group used distilled water to replace the flavonoid solution. The average value retrieved from the aforementioned repeated experiment (three times), was taken into in the formula. The VC solution was performed as a reference using the same concentration of flavonoid solution.

RESULTS AND DISCUSSION

Single factor experiment

Effects of extraction time on the mass of flavonoids

Extraction time plays an important role in evaluating the performance of separation. The extraction process should be as fast as possible in practical application. The effect of time on the mass of extraction flavonoids was investigated ranging from 15 to 90 min when the temperature of the reaction was 50°C and the solid-liquid ratio was 1:20 g/mL. As displayed in Figure 1, the extracting amount of flavonoids increased with the rise of extraction time from 15 to 45 min and reached the maximum value at 45 min. The mass of flavonoids decreased subsequently when extraction time continued to rise from 45 to 90 min. The mass of flavonoids extracted from *Suaeda salsa* could not be improved as the extraction time increased by over 45 min. This might be ascribed to the decomposition of flavonoids over time. Therefore, we selected the extraction time of 30, 45, and 60 min near the largest mass of extraction flavonoids to conduct a response surface analysis.

Effect of extraction temperature on the mass of flavonoids

The temperature has a great impact on the extraction capability of flavonoids, which was carried out ranging from 30 to 70°C. Figure 2 shows the effect of temperature on the mass of extraction flavonoid when the time of reaction was 45 min and the solid-liquid ratio was 1:20 g/m. It can be observed that the mass of flavonoids increased with the increase in extraction temperature. When the extraction temperature reaches about 50°C, the maximum mass of flavonoids was obtained from *S. salsa.* Whereas, if the temperature increased greater than 50°C, the amount of extracted flavonoids decreased slightly which might be caused by destruction of its structure at high temperatures. Thus, the oscillating reaction temperature of the response surface was determined as 40, 50, and 60°C, respectively.

Influence of solid-liquid ratio on the amount of extracted flavonoids

The ratio of solid-liquid takes an important role in the required amount of solvent and the complexity of the extraction process. The effect of the solid-liquid ratio on the mass of flavonoids was displayed in Figure 3. The extraction mass of flavonoids increased with the increase of the solid-liquid ratio from 1:10 to 1:20 g/mL and decreased as solid-liquid ratio rising from 1:20 to 1:35 g/mL. The maximum extraction mass of flavonoids was achieved at 1:20 g/mL. Hence, the solid-liquid ratios of

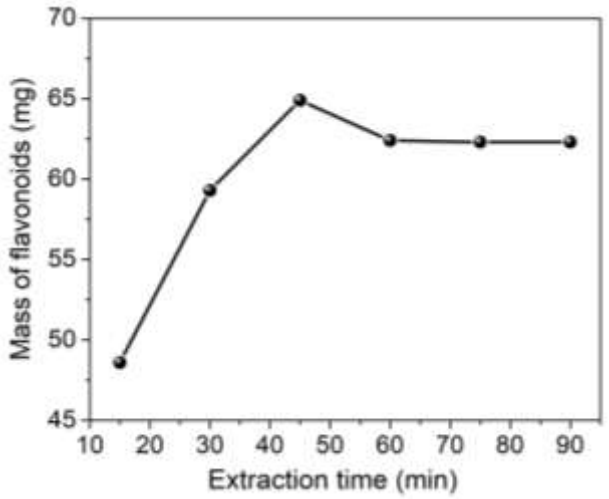


Figure 1. Effect of extraction time on the mass of flavonoids.
Source: Author

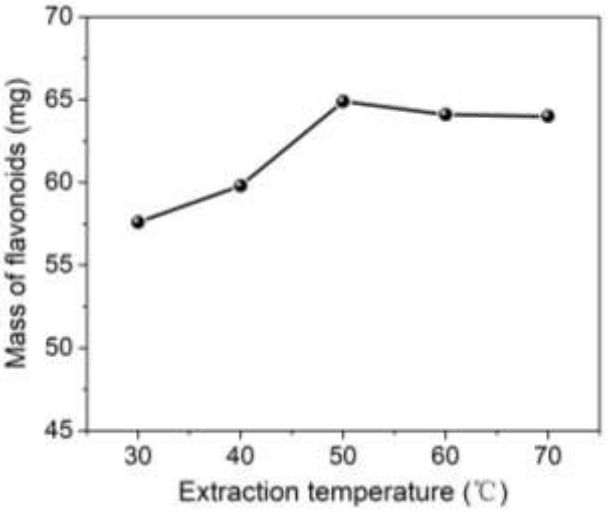


Figure 2. Effect of extraction temperature on the mass of flavonoids.
Source: Author

1:15, 1:20 and 1:25 g/mL were selected for response surface analysis.

Response surface design test results and analysis

Scheme and results of Box-Behnken design

Design-Expert 8.0.6.1 software with the Box-Behnken model was selected to design an experimental simulation condition. The data in Table 1 was adopted to carry out multiple linear regression fitting and a combination of

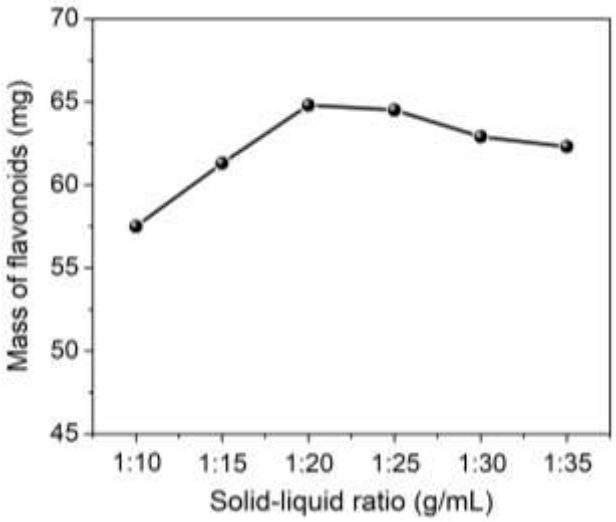


Figure 3. Effect of solid-liquid ratio on the mass of extraction flavonoids.
Source: Author

simulation parameters. Second-degree polynomials equation model of extraction time (A), extraction temperature (B), and solid-liquid ratio (C) with regard to total mass of flavonoids during the extraction process were established by means of multiple linear regression fitting. The equation model is as follows:

$$Y=65.3-0.18A+0.87B+0.95C+0.35AB+0.46AC-0.85BC-1.71A^2-2.31B^2-2.25C^2$$

Variance analysis of response surface regression model

The validity check of the regression equation is an essential index in practical research work. Effect of different reaction factors on the extraction mass of flavonoids from *Suaeda salsa* was further studied. The variance analysis of several important factors in the regression equation was performed as listed in Table 2. The regression equation cannot only predict the results but also be used to analyze the actual data.

This regression equation can analyze the actual data, as well as the prediction of results. The result of the simulation ($F=26.49$, $P<0.0002$) reflects a better-simulated model. In the simulation analysis, the symbol "***" is specially marked, indicating that the simulation is successful and the degree of difference in a response regression model is very significant. A lack of fit ($P=0.9670$) greater than 0.05 demonstrates that the difference is not obvious. The design and experimental error of the response surface model are small, indicating that the model is very reasonable. In addition, the model variability coefficient C.V. is 7.32%, indicating that the test

Table 1. Factors and results of response surface analysis.

Serial number	A [Time (min)]	B [Temperature (°C)]	C [Solid-liquid ratio (g/mL)]	Mass of flavonoids (mg)
1	-1（30）	1（60）	0（1:20）	62.14
2	-1	0（50）	1（1:25）	61.94
3	0（45）	-1（40）	1	61.83
4	1（60）	0	-1（1:15）	59.82
5	0	1	1	61.64
6	0	1	-1	61.35
7	0	0	0	65.15
8	0	0	0	66.12
9	-1	0	-1	61.03
10	1	1	0	62.41
11	-1	-1	0	60.85
12	0	-1	-1	58.14
13	0	0	0	65.86
14	1	-1	0	59.73
15	1	0	1	62.57
16	0	0	0	65.14
17	0	0	0	64.21

Source: Author

Table 2. Variance analysis for the regression model.

Source	Sum of squares	Freedom	Mean square	F value	P value	Significance
Model	80.28	9	8.92	26.49	0.0001	***
A	0.26	1	0.26	0.76	0.4125	
B	6.11	1	6.11	18.14	0.0038	*
C	7.30	1	7.30	21.67	0.0023	*
AB	0.48	1	0.48	1.43	0.2700	
AC	0.85	1	0.85	2.51	0.1569	
BC	2.89	1	2.89	8.58	0.0220	
A^2	12.27	1	12.27	36.43	0.0005	*
B^2	22.40	1	22.40	66.54	<0.0001	***
C^2	21.30	1	21.30	63.27	<0.0001	***
Residual	2.36	7	0.34	-	-	
Lack of fit	0.13	3	0.045	0.0081	0.9670	
Error	2.22	4	0.56	-	-	
Sum	82.64	16	-	-	-	

***Indicates highly significant difference, P ≤ 0. 0001. *Indicates significant difference, 0. 0001 < P < 0. 01.
Source: Author

can be used for statistical analysis. After the significance test of regression equation coefficients, the result shows that P values of B, C, A^2, B^2, and C^2 are less than 0.01, indicating that the extraction temperature, solid-liquid ratio, and binomials of the three factors all have obvious effect. The experimental factors have a nonlinear relationship with the response value because other interaction terms and extraction time significant terms are poor.

The response surface and contour plot of the regression model clearly shows the influence of three factors on the mass of flavonoids from *S. salsa*. The steeper the slope of the response surface, the greater influence of response value on the factor of extraction. While the flat curved surface indicates that the response value is insensitive to the factors. Figures 6 to 8 intuitively reflect the influence of various significant influencing factors on the response value. The shape of contour lines can be roughly divided into ellipses and circles. When the contour lines are

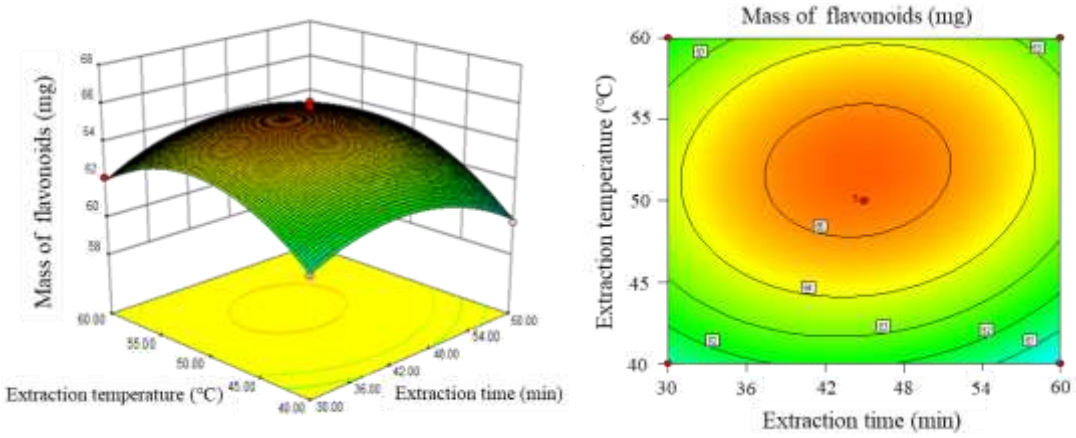


Figure 4. Response surface plot and its contour plot of cross-interaction between extraction temperature and time on mass of flavonoids.
Source: Author

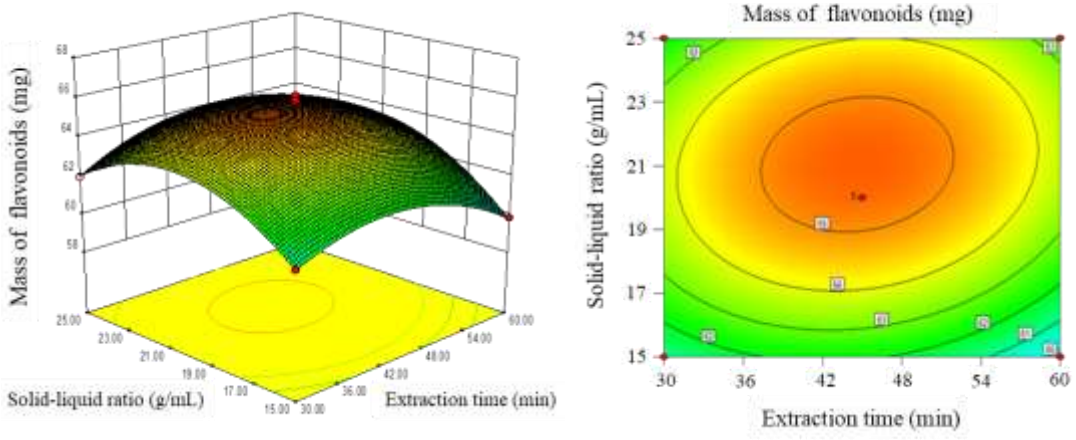


Figure 5. Response surface plot and its contour plot of cross-interaction between time and solid-liquid ratio on amount of flavonoids.
Source: Author

ellipse, the prediction result is better. The curved surface of extraction temperature and time are steep, indicating that the temperature and time are very important for the extraction of flavonoids.

Figure 4 presents the effect of temperature and time on flavonoid extraction. When time keeps unchanged, the curve will gradually rise with the increase of oscillation temperature. When the temperature of the water bath is kept constant, the curve increases greatly with the increase of oscillation time. The results indicate that the two factors could benefit the extraction of flavonoids. Additionally, the corresponding contour lines are elliptical and dense close to the extraction time in the figure, demonstrating that the oscillation time has a greater impact on the extraction of flavonoids than the oscillation temperature.

The interaction between the oscillation time and the solid-liquid ratio is depicted in Figure 5. The dense lines of oscillation time indicate that the mass of flavonoids is more sensitive than the liquid-solid ratio.

The interaction between the oscillating temperature and the solid-liquid ratio is displayed in Figure 6. The mass profile of flavonoids presents a convex shape with the increase of the oscillation temperature and the solid-liquid ratio. When the oscillation temperature is 50°C and the solid-liquid ratio is 1:21.33 mL/g, the response value reaches the maximum value. On the whole, as for the influence of response value, the factor of time is more sensitive than the others to response value. According to model analysis, the optimal extraction conditions were as follows: A=58.63 min, B=52.08°C, D = 1:21.33 g/mL. The maximum yield of total flavonoids was 6.40 mg· g^{-1}.

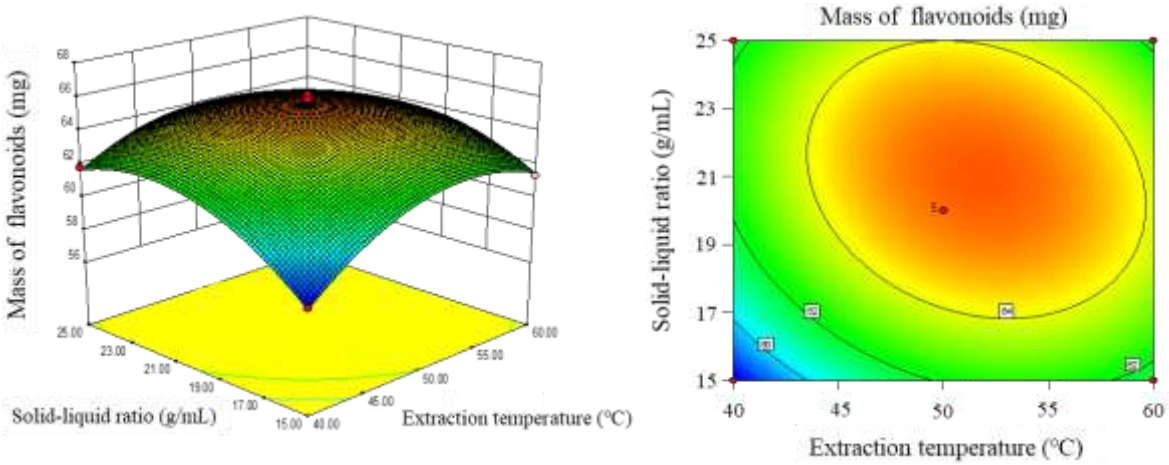


Figure 6. Response surface plot and its contour plot of cross-interaction between extraction temperature and solid-liquid ratio on total amount of flavonoids.
Source: Author

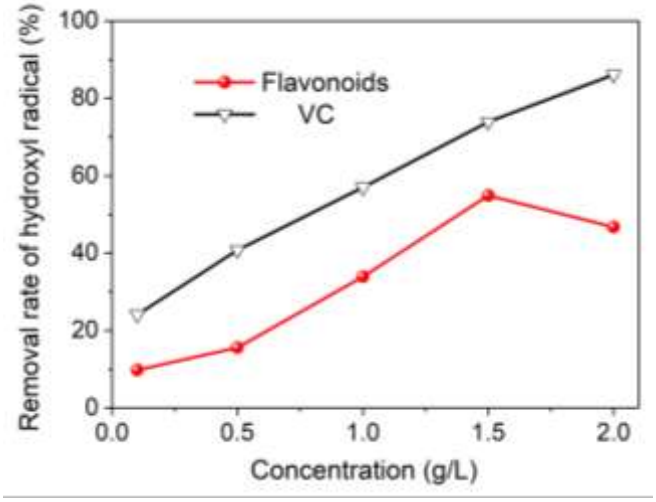


Figure 7. Effect of concentration of flavonoids and VC on the removal rate of hydroxyl radicals.
Source: Author

Capturing ability of flavonoids on hydroxyl radicals

It is vital to study capturing ability of flavonoids separated from *Suaeda salsa* to hydroxyl radicals (Yao et al., 2012; Feng et al., 2015; Zhao et al., 2021). As shown in Figure 7, the removal rate increased from 10 to 54.94% with rising in the concentration of flavonoids, indicating a gradual enhancement in capturing and inhibition of hydroxyl radicals. The higher the concentration, the faster the removal rate. When the concentration increased to 1.5 g/L, the removal rate of hydroxyl radical reached the maximum value of 54.94%. The adsorption capturing capacity subsequently decreased when the concentration of flavonoids continued to rise from 1.5 to 2.0 g/L. The removal rate of flavonoids was weaker than that of VC in general, but the performance was closest at a concentration of 1.5 g/L. From economic considerations, flavonoids have advantage for capturing hydroxyl radicals at the concentration of 1.5 g/L.

Conclusion

Suaeda salsa seed powder was used as raw material to study the optimal extraction process of flavonoids by ethanol. Although the test time is longer than the other modern methods, the simple instrument and common reagents make the procedure facile and cost-effective compared to other modern methods. The extraction process of flavonoids from *Suaeda salsa* is optimized by the response surface analysis on the basis of a test with a single factor. The optimum process conditions: the extraction time is 58.63 min, the extraction temperature is 52.08°C, and the solid-liquid ratio is 1: 21.33 g/mL. Under the optimized conditions, the maximum mass of flavonoids from *Suaeda salsa* is 6.40 mg/g. It has important significance for the research and development of *Suaeda salsa* in saline-alkali land.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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