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Research Article

Hydromorphological assessment in North Morocco: The case of Martil River

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Abstract

The present study is about an assessment of the Martil River restoration, which crosses Tetouan and Martil city in Northern Morocco. The evaluation compromises rainfall occurrence of 30 years, riparian habitats, and the river flow of 12 years. The rainfall analysis was carried out by the Standard Precipitation Index (SPI). Only three stations that contain continuous monthly precipitation data were considered. The river health and water quality were determined by the QBR (Riparian Habitat Quality), while the environmental flow was estimated by Tennant method. SPI results show a rainfall increment pattern with regular, extreme, and plentiful downpours causing rough deluges and floods. The ultimate flow result to support the river habitats was found 60% of the natural flow in the main channel. This study highlights the stream's unhealthy water, which falls within the low-quality water category downstream the river under anthropogenic pressure, while good to excellent quality was scored upstream the watershed. Tennant outcomes were discovered 2.40 m^3/s as 30% and 5.51 m^3/s as 60%, while 10% of the flow was found to be not adequate for habitats in the Martil River.

Keywords: *Water resources, Standard precipitation index, QBR index, Environmental flow, Hydromorphology, Martil River.*

1. Introduction

As the population grown in cities around the world, urban rivers always suffer from anthropogenic activities. Negative impacts of water quality on stream environments coming about because of expanded contribution of biogenic substances and contamination from sewage, farming or industry (Hajdukiewicz *et al*., 2017). Until the 1950s, it was commonly recognized that environmental perturbations in the river systems were related to pollution, and it was considered as the well-known explanation of change(Paul, 2010). Some acknowledgment is at last being given to in-stream regimens to secure the river habitat's entourage(Donald Leroy, 1976).

Nonetheless, one of the main difficulties of the 21 century is to oversee water and other common assets so human requirements can be fulfilled without harming the climate(Pastor *et al*., 2014). Assessment of environmental change impacts on regular water resources is explicitly prominent in dry and semi-dry regions. This is because of the fragility of water resources to environmental change; a minor change in natural components may achieve critical varieties of the hydrological cycle(Abghari *et al*., 2013).

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Riparian conditions are likewise of unprecedented organic importance since they are depicted by high biodiversity, the limits of an ecoregion incorporate a zone inside which significant biological and transformative cycles most unequivocally interact (Arthington *et al*., 2004). Moreover, river's riparian provides few significant environmental administrations, including the capacity and purging of water and the provisioning of producing natural surroundings for fish (Garssen *et al*., 2017). This can just necessitate that water and common asset supervisors guarantee the security of riparian vegetation (Magdaleno, 2014).

Accordingly, evaluating and assessing the biological system has become a need for preservationists as a method of comprehension and limiting as many natural effects as possible (López-Baucells *et al*., 2017).

Consequently, a few hydromorphological evaluation techniques have been created, with a large portion of them focusing on the elements of hydrology, geomorphology and riparian zones (Stefanidis *et al*., 2020). Nonetheless, it has been seldom executed over since a long time ago reestablished stream fragments and has been rarely evaluated while considering waterway conditions before reclamation (Martínez-Fernández *et al*., 2017). This situation has undergone a

global reassessment in the previous years, needing to enact a series of far-reaching institutions of which the river's hydromorphological statues are amounts the most important.

(Vaughan *et al*., 2009) had directed orderly audits and examinations of the advancement example of hydromorphology, and they scooped three significant perceptions which can be made with respect to the connections between valley morphology, width of channel and substrates of riverbanks: (i) current scientific understanding is generally poor, especially at the quantitative levels required for effective prediction and management (ii) they emphasized on the urgent need to improve the understanding of ecology–hydromorphology, and finally, (iii) if river environments are to be managed effectively in the future, it is vital that such changes are both understood and clearly communicated to practitioners.

This paper comes as a supplement for the Martil valley development project situated in the North of Morocco. The project consists to buffer flood water seasonal runoff in order to restore river channel in such a way as to maintain its economic and social value in the midst of high-density urban development.

In this scheme, this research will carry a hydromorphological assessment of Martil River's health with the study of several influencing factors to balance between human needs and nature concerns. The dataset of 30 years of precipitations and river flow velocity were collected from different meteorological stations. While the riparian habitats index was estimated by field observation measurements and analyzed. These data are interpreted in order to assess the drought conditions in the area, evaluating the riparian river vegetation and estimating the environmental flow of Martil River.

2. Study area

Located in the northwest of Morocco, the province of Tetouan is one of the eight prefectures that make up the Tangier-Tetouan-Al Hoceima Region (Prokos *et al*., 2016). The Martil watershed is situated in the North-West of the Riffian chain between 35° 15' and 35° 44' of Northern latitude and between 5° 18' and 5° 38' of Western longitude. It originates from Chefchaouen hills and eventually drains into the Mediterranean Sea. The watershed includes an area of 1170km^2, and it is considered one of the most important watersheds in the North of Morocco. Located in the northwest of Morocco, the province of Tetouan is one of the eight prefectures that make up the Tangier-Tetouan-Al Hoceima Region (Prokos *et al*., 2016). The basin reaches a maximum elevation of about 1800 m and includes both cities of Tetouan and Martil together with 14 smaller communities and a total population of 445,000.

The study area with a length of 12km drains from Tamuda Bridge and flows downstream until the low-lying area in Martil city (Fig1), it is known for its abundant wildlife and relatively unaltered surroundings by its natural location. In this section, the channel forms numerous meanders and the width of the riverbed varies between 85m and 200m. The Martil River is mainly fed by precipitations and adjacent rivers (Khemis and Mhajrate) situated in the upstream of the watershed, the basin is characterized by topographical and edaphological transition from upstream to downstream.

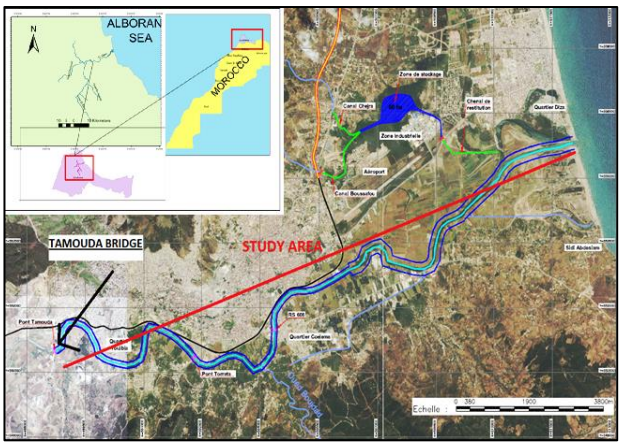


Fig.1 Study area

3. Materials and methods

This paper will investigate different parameters of this restitution which can be used to determine (i) the drought and wet periods through rainfall data in the Martil watershed, (ii) riparian vegetation quality of Martil River and (iii) the environmental flow basing on the current flow in the main channel. This appraisal was made conceivably through the assortment and examination of precipitation in a period of thirty years. A sum of five riparian examples from across upper, mid and lower catchment was gathered and investigated for the design cover in geomorphological sort boundaries. Throughout this current work, we have also studied how environmental flows can be integrated at the project of restoring Martil River while the channelization works still on the first section.

3.1 Field data collection

The data sets, comprising rainfall of 30 years period which was collected from the Loukkos hydraulic basin agency (ABHL). Riparian quality indexes (QBR) were examined through five different accesses point of the River, and Tennant method was set to examine the environmental flow in the Martil River. The fieldwork in five distinct areas was performed along the Martil waterway.

3.2 Standard Precipitation Index

Created by McKee *et al*. (1993), the standard precipitation index (SPI) is an indicator determined

from the verifiable precipitation record at a certain gauging station, where precipitation collection throughout some undefined time frame is contrasted with that equivalent timeframe throughout the chronicled record at that area. It is viewed as the most generally utilized guide and is a proportion of the precipitation in a certain region for a time of at least 30 years (Vidhya Lakshmi *et al*., 2020). Of the 5 gauging stations that the basin agency posed, only three stations that contain continuous monthly precipitation were taken into account. A prescribed analysis of rainfall data was carried to verify if the modality in the river flow follows the trends for the precipitations. Positive value of SPI esteems wet conditions; the higher the SPI, the more surprisingly wet a timeframe is. While the negative values esteem dry conditions; the lower the SPI, the more uncommonly dry a timeframe is. Wetter and drier environments can be addressed similarly, and wet periods can likewise be checked utilizing the SPI. This can be done because of the standardization of SPI (Costa, 2011). The periods selected in this research were 3, 6 and 12 months, and the standard precipitation index was calculated through RSTUDIO software which can be downloaded from (https://drought.unl.edu/droughtmonitoring/SPI/SPIProgram.aspx), and results were projected in excel.

3.3 Riparian Quality Index (QBR)

The QBR index developed by Munne and others on 2003, was created in purpose to assess the riparian forests of Mediterranean area streams (Colwell & Hix, n.d.). The QBR index can be used widely by environmental Scientists at several scales and could be very useful to classify the health of the river's riparian. Inside the recently considered cases, the QBR test ends up being free of territorial contrasts in riparian plant local area types (Munné *et al*., 2003).

The index varies between 0 and 100 as the maximum score and it is based on four main aspects (vegetation continuity, cover structure, cover quality and the alteration of the channel), it can easily be filled by observation on the field.

In this research, five sampling locations were selected with different characterizations, each location was about 70 meters in length along the channel. All components of the QBR index were evaluated in order to determine whether the final score is sufficient to be more accurately reflecting the classifications of the Martil River's riparian forests. The observers were able to identify the native and non-natives plant species.

3.4 Tennant method

The Tennant estimation method which communicates suggested streams as a rule of yearly or month-to-month release (P. Anderson, 2013), is generally an applicable hydrological average method over much of the globe today, it is consistent with the national requirements in many countries, and it is considered as an acceptance practice. Instead of zeroing in on the enhanced climate for single species, this technique incorporates the protection of streams' overall biological uprightness (Suwal *et al*., 2020). This study used two hydrological-based methods, namely, the Tennant method and the flow duration curve method.

It is not completely clear in the method why this average was chosen, but from this research, it appears to be mainly due to the simplicity of calculating the average and its ready availability from hydrological datasets compared to percentiles or other statistical values at the time. The environmental flow assessment in Martil River began first by visiting the river to observe, study the flow regimes and approximating the percentage of the average flow. Levels and the volumes and durations of the overflows were examined. The minimum as well as the ideal environmental flow in the Martil River was calculated strictly by Tennant method. These steps are clearly intended to produce custom, flow recommendations for a given river reach based on detailed hydrology, hydraulic and ecological studies, including field studies. In outline, there is a lot of rich involvement with past examinations on the utilization of the Tennant strategy, to consider the effect of aquatic living beings on environment wellbeing and human exercises (Zhao *et al*., 2021).

4. Results

4.1 Rainfall analysis and SPI results

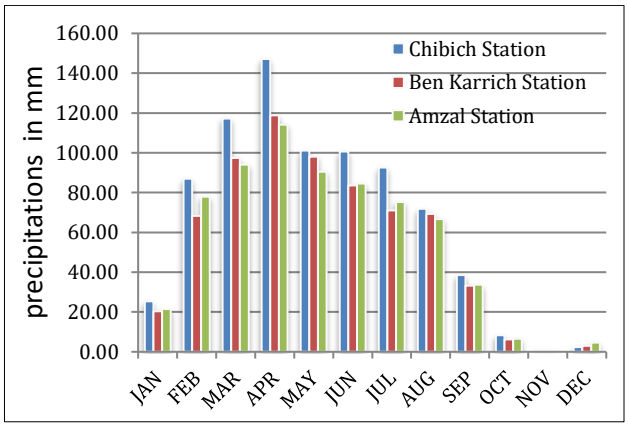
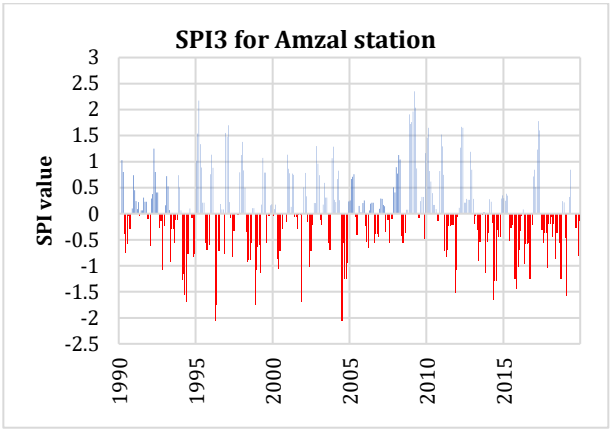
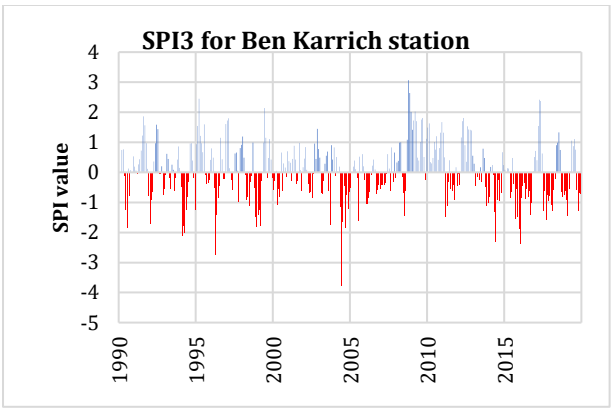


Fig.2 Bar graph showing monthly rainfall.

The bar chart shows the average rainfall recorded in the three stations in the Martil watershed. This semi-arid area receives an average of 921mm of rainfall concentrated during particular times of the year. The minimum score was recorded as 215mm, while the maximum value was 1555mm. The rainfall occurring during the summer is noticed to be 1% from the annual precipitations, while 31% and 41% are the percentages of rain during autumn and winter seasons.



(a)



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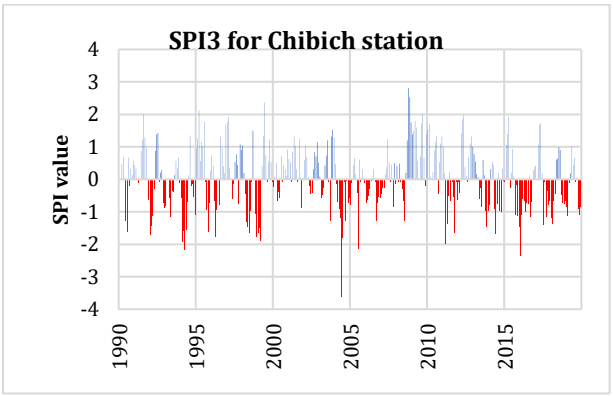
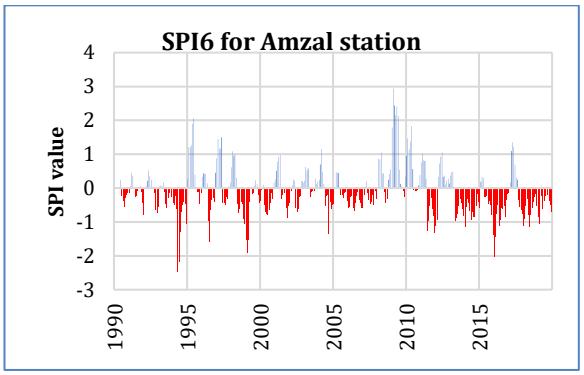


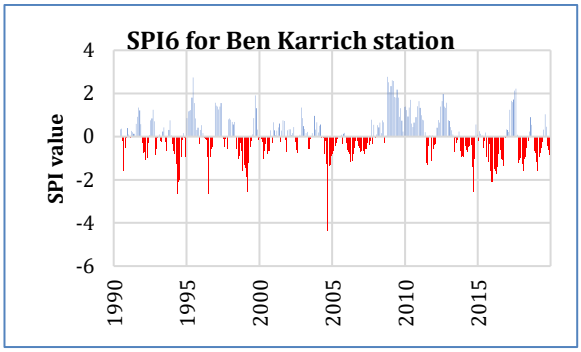
(c)

Fig.3 Graphs of SPI3 (a)Amzal Station; (b) Ben Karrich Station; (c) Chibich Station

The SPI of three months scale for the long stretches of July, August, September, and October show the worldly underneath elements and an extremely dry spell period in 2004 in Tetouan. While most of wet events did not exceed a value of +2.0 in all stations, the negative values were observed to surpass 3.0 in sometimes. It very well may be seen that during the dry season in 2004, negative SPI esteems which surpassed – 3.5, had been seen sever in the two stations Chibich and Ben Karrich, which demonstrate that the most shortage in precipitation was in this year. All stations show alternately dry spell period and wet periods during the studied period.



(d)



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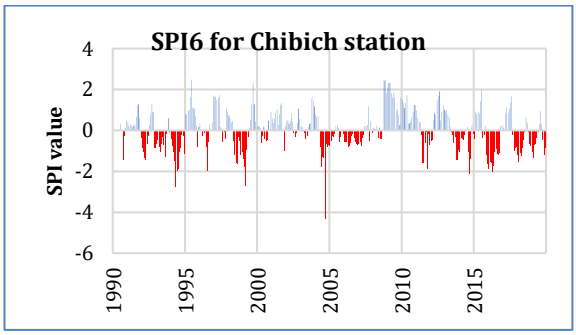
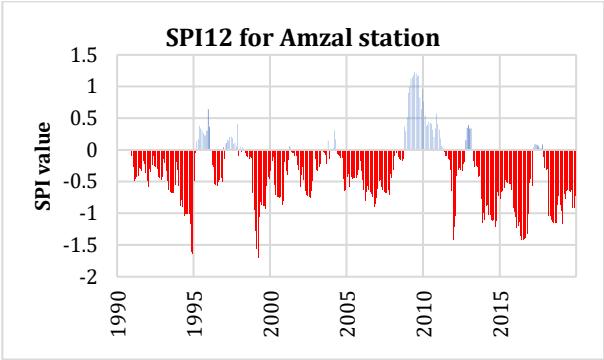


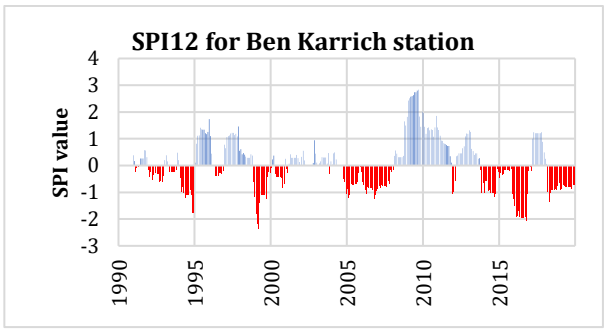
(f)

Fig.4 Graphs of SPI6 (d)Amzal Station; (e) Ben Karrich Station; (f) Chibich Station

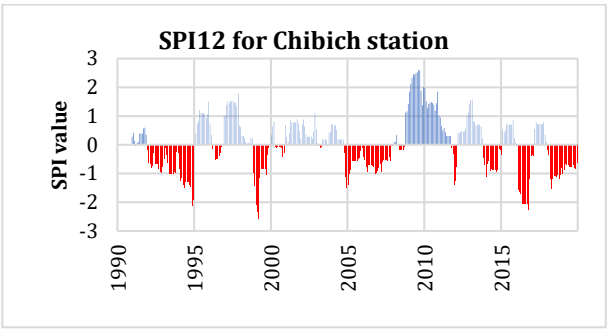
The exceptional records of SPI 6-month period demonstrate practically similar lists as SPI3 at Chibich and Ben karrich (this is due to the short distance between the two gauging stations). Aside from an extreme dry spell period in 2004 with an exceptional drought aggressive record (-4.2), the remainder of the time frame starting from 2008 shows reasonable wet periods in winter just as thorough dry season in summer. A very wet period was enrolled (SPI>2.9) during the winter of 2009. Dry spell periods are noticed to be severe but not continuous prevalently than sodden lengths somewhere between 1990 and 2015. In general, it can be observed that during the 30 years duration recorded in Ben Karrich and Chibich stations, the dry season time frames were more serious but shorter than the wet periods. In general, an expanding pattern in the SPI values figured between 2008 and 2012 can be described by severely wet.



(g)



(h)



(i)

Fig.5 Graphs of SPI12 (g)Amzal Station; (h) Ben Karrich Station; (i) Chibich Station

Considering the month of December, the dry spell conditions as shown by the SPI12 were unprecedented in the colder time of year of 1990 for the thirty years precipitation record, and the low SPI mirrors the aggregate impact of sequentially low and probably the driest year. While this dry spell during the turn of the three last long stretches of the 20s has occasionally been moderated, the rest of the time frame was ordinarily wet and not a solitary dry season occasion was recorded. However, the very satisfied wet period between 2009 and 2012 indicates rich hydrological conditions.

Indeed, a slight difference can be noticed between the records of the three stations, but the three stations have a similarity regarding the period of drought events.

The drawn-out time arrangement for SPI at unsurpassed scales was examined to have a reasonable comprehension of the fleeting variety of SPI at chose stations. The quantity of years remembered for the kind normal should be adequately huge to screen out the clamor and sufficiently little to protect the specificities of the inconsistency type (Chbouki *et al.*, 1995).

4.2 QBR results

Regarding the QBR results, the index was filled by three observers in order to contain better results. The measurements were taken on two separate days during the winter season. The great diversity between sample locations had resulted with values ranged from 0 to 90. Analysis of the vegetation of both sides showed an acceptable quality, especially where the water way areas are in good shape. In this context, LCT1 and LCT2 are of excellent quality (85% and 60%) and LCT3 can be classified as good quality (38%). This part of the river is bordered by the willow shrubs, which are adapted to colonizing nutrient-poor, coarse-grained river bars and are capable of regenerating quickly following the disturbance events. LCT4 was rated poor quality (12,7 %) followed by LCT5 which was found as the lower vegetation quality with a value of 1,67%.

Fig.5 Sample locations

4.3 Environmental flow

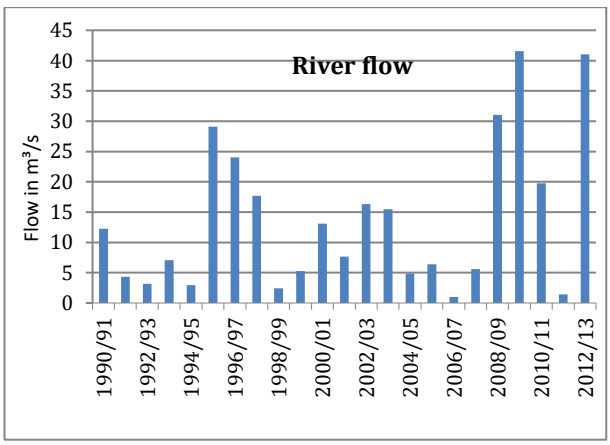


Fig.6 Yearly river discharge

The results of the bar chart additionally show that these periods have essentially different mean quantities demonstrating the suspicion of cyclic behavior. The justification for this could be found in land-use changes inside the catchment or expanded deliberations for the water system. Additionally, changed precipitation attributes could affect these flows.

Table 1 Results of Tennant method for the year 1994

Discharge calculated based on Tennant method			Suggested percent of average annual flow			Description
January-June		July-December	January-June		July-December	
60-100% of the average flow						optimum range
5.85		12.44	40%		60%	Outstanding
4.39		10.37	30%		50%	Excellent
2.92		8.30	20%		40%	Good
1.46		6.22	10%		30%	Fair
1.46		2.07	10%		10%	Poor
1.46-0		2.07-0	10% to 0			Severe degradation

Table 2 Results of Tennant method for the year 2010

Discharge calculated based on Tennant method			Suggested percent of average annual flow			Description
January-June		July-December	January-June		July-December	
60-100% of the average flow						optimum range
34.71		90.08	40%		60%	Outstanding
26.03		75.07	30%		50%	Excellent
17.35		60.06	20%		40%	Good
8.68		45.04	10%		30%	Fair
8.68		15.01	10%		10%	Poor
8.68-0		15.01-0	10% to 0			Severe degradation

Table 3 Results of Tennant method for the year 2011

Discharge calculated based on Tennant method			Suggested percent of average annual flow			Description
January-June		July-December	January-June		July-December	
60-100% of the average flow						optimum range
3.20		5.51	40%		60%	Outstanding
2.40		4.60	30%		50%	Excellent
1.60		3.68	20%		40%	Good
0.80		2.76	10%		30%	Fair
0.80		0.92	10%		10%	Poor
0.80-0		0.92-0	10% to 0			Severe degradation

Depending on figure 27, it very well may be obvious that the arithmetic means of the stream in Martil Waterway streams change massively. The upside of utilizing a rate scope of 10, 20, 30, 40 and 60%, as demonstrated in tables above, is that its show the base stream needed during the low stream time frame and consider reasonable stream conditions for biota and recreational exercises during the high stream time frame.

The results of the Tennant technique for hydrologic information of Martil Stream during 1994,2010 and 2011 are shown individually in **Table 1, 2** and **3**. As per these tables, the normal yearly progression of spring-summer and fall winter was determined. Since the stream in 2010 was classified as a natural flood, a combination of massive rainfall occurrence had perturbed the river flow during the wet months. Thus, the aftereffects of this year cannot be embraced as environmental flow. However, the general frequencies of the two years 1994 and 2011 give off an impression of being very comparative. As per Table 13 and Table 15, in the long stretches of June, July, August and September, the natural flow of the river could be described as mater variable. These outcomes demonstrated that the environmental flow was not given along the waterway. 30% and 60% of the yearly normal stream were considered as reasonable and ideal conditions for endurance of river organisms. These values were identical to 4.39 m^3/s and 12.44 m^3/s, respectively for the year 1994. For 2011, Tennant outcomes were discovered 2.40 m^3/s as 30% and 5.51 m^3/s as 60%.

The most important use of the hydrological data is to support the lower threshold of 10% of average annual flow. The presentation of this hydraulic habitat's basis for the percent of average flow threshold strengthens the validity of the method for application in rivers like these used in the method of development. Such hydraulic justifications for flow recommendations were becoming the state-of-art in the environmental flows' community.

4.4 Flow curve duration

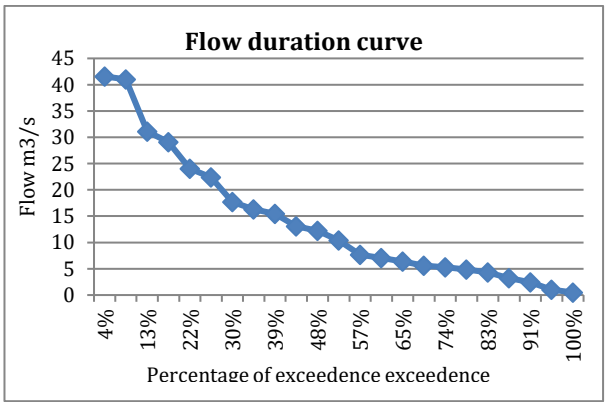


Fig.7 Flow duration curve

The state of the flow curve in its upper and lower areas is especially important in assessing the stream and basin attributes. the nonparametric assessment methodology gives a summed-up option in contrast to assessing the size and recurrence of the total continuum of yearly stream flow going from a T-year yearly least low stream to the T-year yearly most extreme flood stream (Vogel & Fennessey, 1994). The state of the bend in the high-stream area of Tetouan shows the kind of flood system the Martil watershed is having. It tends to be seen from the bend that high streams for brief periods would for downpour caused flood occasions.

5. Discussion

The SPI has three possible inconveniences, the first being the presumption that an appropriate hypothetical

likelihood circulation can be found to display the crude precipitation information preceding normalization. The first and essential bit of leeway is straightforwardness The SPI has three principal preferences. By dodging reliance on soil dampness conditions, the SPI can be utilized viably in both summer and winter. It depends exclusively on precipitation and requires just the calculation of two boundaries (wet and drought). The SPI's subsequent favorable position is its variable time scale, which permits it to depict dry season conditions significant for a scope of meteorological, agrarian, and hydrological applications. This fleeting adaptability is additionally useful for the investigation of dry season elements, particularly the assurance of beginning and suspension, which have consistently been hard to follow other records. The other preferred position comes from its name as normalization, which guarantees that the recurrence of outrageous occasions at any area and on any time scale is reliable. In the end, they said that the index is likewise not influenced antagonistically by geography.

The QBR record, in its general appraisal, is a marker that gives us the essential data with respect to the criticalness of rebuilding, i.e., in the event that it gives us an incentive under 50, there is an inescapable requirement for recuperation; if the worth is more than 90, for this situation, protection will be an administration measure. After a first worldwide investigation, it is needed to break down every one of the components of the list independently, as markers of various components (complete riparian vegetation cover, vegetation cover structure; vegetation cover quality and waterway channel modifications). In the event that we have a low score on the QBR1 the primary issue is a low thickness of riparian backwoods and additionally availability issues with the adjoining woods. Subsequently, explicit measures might be planned for this situation, like reforestation with local species, just as fortifying the environmental hall work. On the off chance that the low score is in the QBR2, the issue might be the presence of direct reforestation, the appropriation of trees in patches, which can be settled by restocking deforested zones, improving the association among trees and bushes (among different measures). The QBR3 is a marker of the presence of native trees, design display, and so forth. At last, if the QRB4 has a low score, human intercessions that adjust the waterway channel ought to be examined. To consider the specialized, monetary, and authoritative possibility of the destruction of the deterrent would be the following stage.

The Tennant method is considered one of the oldest methods in assessing the environmental flows, it is very known for its ecological considerations. Furthermore, it can be used to recommend flows to meet multiple objectives. The method was published by Donald Tennant in 1975 as a report of the USA Fish and Wildlife Service. As first investigation, Tennant (1976) analyzed cross sections of 11 streams in Montana and other states in the United States and found that the bottom width, velocity, and flow depth increase significantly from no flow to 10% of the main annual flow (Kim & Choi, n.d.). Tennant suggested that 10% of the main annual flow provides the minimum habitat conditions for river ecosystems. In addition, Tennant proposed an optimal status for aquatic ecosystem which is 60% to 100% of the annual flow average (Kim & Choi, n.d.).

It is not completely clear in the method why this average was chosen, but it appears to be mainly due to the simplicity of calculating the average and its ready availability from hydrological datasets compared to percentiles or other statistical values at the time. Tennant also had written that the average flow can be accurately estimated by simple measures of channel geometry. In this way, he proposed that even without accessible hydrological information, the strategy can be applied. Some small portion of normal stream is fundamental to keep a decent stream climate, is the essential suspicion of this technique (Amrit *et al*., 2019).

Conclusions

The results of the analysis found the SPI (scale of 12 months) had also scored some dry but not severe periods. The chance of dry periods brought about no continuous dry events of dry seasons were discovered to be critical and entirely factor during the study period frame. These discoveries propose that the precipitation attributes of Martil watershed can be sufficient to the future Dam foundation upstream Martil Stream. However, the standard precipitation file computations depend just on precipitation estimations, which could be not adequate in a drawn-out dry season appraisal nearby.

The appraisal, for assurance of the vegetation nature of Martil waterway has uncovered an extraordinary changeability of plants entourage and species across various sections of the catchment. The expanding pattern of Martil River riparian are mostly connected with an expansion in land use advancement and occupant thickness, like farming exercises or the chaotic buildings moving from upland to swamp. Other further territories of the stream are losing more soil because of contamination brought about by modern exercises, which had prompted the deficiency of land at the stream banks.

The environmental flow by Tennant technique was found to varies between 5.51 and 12.44 m^3/s between July and December, while it ranges somewhere between 2.4 and 4.39 m^3/s during the rest of the months, these qualities were determined by Tennant strategy in reason to arrive at solid living spaces. The limit of the natural stream ought to not surpass 24.94m^3/s while the lower flow supposed to not go underneath 0.29m^3/s. The low stream is the base stream for having a waterway alive and moderating its biological system in basic condition for a brief timeframe period.

These values of environmental flow can be easy to achieve where riparian vegetations are in good shape. The examination uncovered that in the monsoon period,

the level of normal yearly stream increments with expanding in standard precipitation index values, the higher the SPI values are, environmental stream conditions are acceptable.

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