# DROUGHT AND ITS RECURRENCE: IMPLICATIONS FOR WATER RESOURCES DEVELOPMENT IN NORTHERN NIGERIA

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***Abstract***
*The study analyzed the occurrence and return periods of drought for 6 locations covering the Guinea, Sudan and Sahel savanna zones of Nigeria for different time periods. Standardized Rainfall Anomaly Index (Van Rooy, 1965) was utilized for drought characterization. The analyses show that 31 out of the 69 years analyzed for Kaduna were drought years. For the 71-year time period analyzed for Minna and Bida, 37 and 33 years, respectively were characterized as dry years. Thirty-two out of the 55 years analyzed for Sokoto were drought years, 21 out of the 42 years analyzed for Nguru were characterized as drought years while 32 out of the 51 years analyzed for Gusau were dry years. The recurrence interval of drought were 2.27, 1.92, 2.17.1.72, 2 and 1.59 years for Kaduna, Minna, Bida, Sokoto, Nguru and Gusau respectively. Given these findings, the need for robust water resources management and development is underscored. Relevant River Basin Development Authorities (RBDAs) should focus on increased establishment of dams and irrigation projects and inter basin water transfers. In addition, water supply planning, demand management and drought impact minimization be prioritized.*
**Keywords:** Drought, recurrence interval, water resources, dams, irrigation

## Introduction

The phenomenon known as drought has no universal definition and as such various definitions exist. Most of the definitions, however, consider drought as significant decrease in water availability over a temporal and wide spatial extent (Tsakiris *et al.,* 2007). According to Smakhtin and Hughes (2004), drought is a multi-faceted phenomenon originating from low precipitation which affects soil moisture, surface water, groundwater and humans depending on its duration and severity. The US Army Corp of Engineers (1994) considers drought periods as periods when natural or managed water systems are unable to provide adequate water to meet established anthropogenic and environmental needs due to deficits in precipitation or stream flow.

In the northern region of Nigeria especially in the Sudano-Sahelian Zone (SSZ), drought is a recurrent phenomenon. According to Demaree and Nicolis (1990), the sahelian drought is a "recurrent periodic event related to ongoing transitions between a stable state of 'quasi-normal rainfall and a stable state of low rainfall" (p.551). According to Oladipo (1993), the severe and sometimes widespread drought experienced in northern Nigeria is partly due to the large inter-annual variability of rainfall in the region. In the 20$^{th}$ century, a total of eight major drought events were recorded. These spanned the periods 1904 to 1912, 1914 to 1930, 1942, 1950 to 1952, 1966 to 1968, 1969 to 1974, 1983 to 1984, and 1987 (Nyong, 2001).

Some of the consequences of drought in northern Nigeria include ecosystems modification, dislocation of social and economic activities, crop failure, livestock death, declining water table including shortage of water for domestic, industrial and agricultural purposes and increased temperature and sedimentation of surface water as a result of increased evaporation and transportation of loose soil particles (Ekpoh and Nsa, 2011).

In recognition of the hazardous nature of drought, a number of methodologies have been developed to characterize, quantify and monitor drought in order to mitigate some of its impacts. One of such is the index method. The various drought indices in existence were developed to characterize drought and its statistical properties in order to enable scientists to quantitatively assess climatic anomalies in terms of intensity, duration, frequency and spatial extent. It also allows for the analysis of historical drought and their occurrence probabilities, as well as making it easier to communicate information on climatic anomalies to the layman and the general populace (Tsakiris *et al.,* 2007).

In view of the above highlighted reasons, this study assesses the occurrence of drought at six selected locations in northern Nigeria using an index method known as Rainfall Anomaly Index developed by Van Rooy (1965). Probabilities of occurrence and recurrence intervals were also computed in order to estimate the frequency of drought occurrence within the selected locations.

**Study Area**

Kaduna, Minna, Bida, Sokoto, Gusau and Nguru (Figure. 1) are located in northern Nigeria. The region is located between 6° 27'N and 14°N and longitude 2° 44'E and 14° 42'E (Oladipo, 1993). The study locations occupy ecological zones spanning the northern Guinea Savannah, Sudan Savannah to the southern fringes of the Sahel. The climate of northern Nigeria is semi-arid tropical climate controlled by two air masses, the dry and dusty continental air mass which predominates between October and March, and the rain-bearing tropical maritime air mass which prevails between April and October. Numbers of rain days vary between 40 and 100 per annum, while mean annual rainfall varies between 500 and 1,000 mm (Woo and Tarhule, 1994).

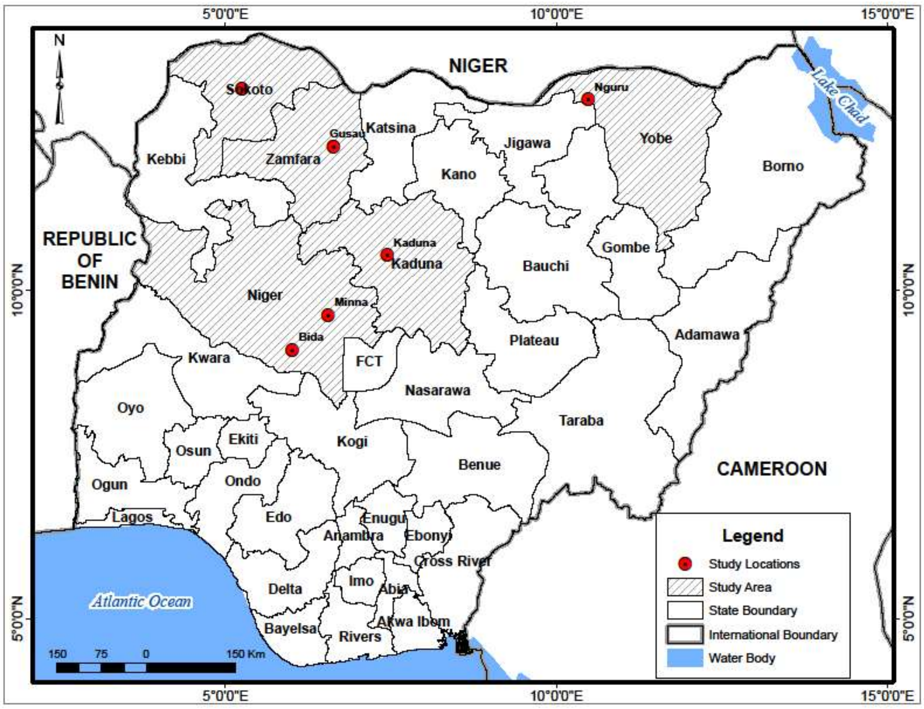


**Figure 1:** The Study Locations

Major rivers around the study locations include Rivers Kaduna, Kangimi, Chanchaga, Landzu, Sokoto, Rima, Zamfara, Ka, Hadejia, Jama'are and Yobe. For places like Sokoto and Gusau which is located within the Sokoto groundwater basin, groundwater can be obtained from major aquifers such as the Gwandu formation, Kalambaina formation and Rima aquifer (UNEP and WRC, 2008). For places like Nguru which is located in the Komadugu - Yobe River

Basin, the Chad Aquifer from the Chad geological formation serves as the sole source of groundwater supply (UNEP and WRC, 2008).

**Methodology**

Rainfall data for six synoptic stations, Kaduna, Minna, Bida, Sokoto, Gusau and Nguru were collected from the Nigerian Meteorological Agency (NIMET), Oshodi, Lagos. Rainfall data spanning different time periods (Table 1) were used for the study. To detect periods of drought occurrence at the study locations, Rainfall Anomaly Index (Van Rooy, 1965) was used.

**Table 1: Synoptic Stations and Time Span of Data**

| Station | period | No of Years |
|---|---|---|
| Kaduna | 1943-2011 | 69 |
| Minna | 1941-2011 | 71 |
| Bida | 1941-2011 | 71 |
| Sokoto | 1951-2005 | 55 |
| Gusau | 1960-2010 | 51 |
| Nguru | 1960-2001 | 42 |

Rainfall Anomaly Index was computed based on the formula;

$$RAI = \frac{+}{3} . \frac{P-\overline{p}}{\overline{E}\,\overline{p}} \qquad \text{………………} (1)$$

Where P = Annual Precipitation

$\overline{P}$ = Average Annual Precipitation

$\overline{E}$= Average of Ten Extremes for the Study Period

For the detection of negative anomalies (drought events) the prefix is negative and $\overline{E}$ is the average of the 10 lowest precipitation totals (driest years).

The probability of drought occurrence was determined based on the computation of absolute empirical probability. This is expressed as;

$$P = \frac{n}{Ny} \qquad \text{…………………}(2)$$

Where P = Absolute Probability of Drought

n = Number of Occurrences of Drought

Ny = Total Number of Possible Occurrence (The Study Period)

Drought recurrence intervals or return periods were computed based on the formula;

Where $R_i$ = Drought Recurrence Intervals

P = Absolute Probability of Drought

**Results and Discussion**

**Drought Occurrence**

The results of the Rainfall Anomaly Index (RAI) are graphically presented in Figures 2 to 7. The results of the RAI for Kaduna shows that 31 out of the 69 years (45 percent of the years) were dry years, with 3 dry years recorded between 1943 and 1949. Between 1950 and 1959, 1960 and 1969, 1970 and 1979, and 1980 and 1989, a total of 4, 1, 3 and 8 years, respectively, were characterized as drought periods. Between 1990 and 1999, 2000 and 2009, and 2010 and 2011, computed dry years were 5, 6 and 1 year, respectively.

For Minna, a total of 37 out of the 71 years (52 percent) were characterized as drought periods, with 4 years of drought recorded between 1941 and 1949. In the 1950s, 1960s, 1070s, 1980s and 1990s, a total of 5,4,5,9 and 5 years, respectively were computed as years for each decade. Between 2000 and 2009, 4 years were computed as drought years, and between 2010 and 2011, 1 year was characterized as a dry year.

For Bida, 33 out of the 71 years (46 percent) of rainfall data analyzed were characterized as drought years, with 5 years of drought recorded between 1941 and 1949. For the 1950s, 1960s, 1970s, 1980s and 1990s, number of drought years were 3,2,5,6 and 6 years, respectively. Between 2000 and 2009, 4 drought years were recorded while years 2010 and 2011 were also characterized as drought years.

For the 55 years of rainfall data analyzed for Sokoto, 32 years (58 percent) were characterized as drought years. Between 1951 and 1959, 4 years were drought periods, while between 1960 and 1969, and between 1970 and 1979, a total of 4 and 6 years of drought were recorded. Furthermore, the result of the RAI shows that the 1980s were all drought years while 50% of the 1990s were also dry years. Between 2000 and 2005, 3 dry years were recorded respectively.

Fifty percent of the rainfall data analyzed for Nguru were characterized as drought periods, with the 1960s and 1970s recording 2 and 3 drought years, respectively. A total of 9 dry years and 2 dry years were recorded during the 1980s and 1990s, respectively, while the years 2000 and 2001 were also characterized as drought years.

63% of the years between 1960 and 2010 were characterized as drought years for Gusau, with the 1960s, 1970s, 1980s and 1990s recording 5, 9, 8 and 4 years of drought, respectively. Between 2000 and 2009, a total of 6 years were characterized as dry years.

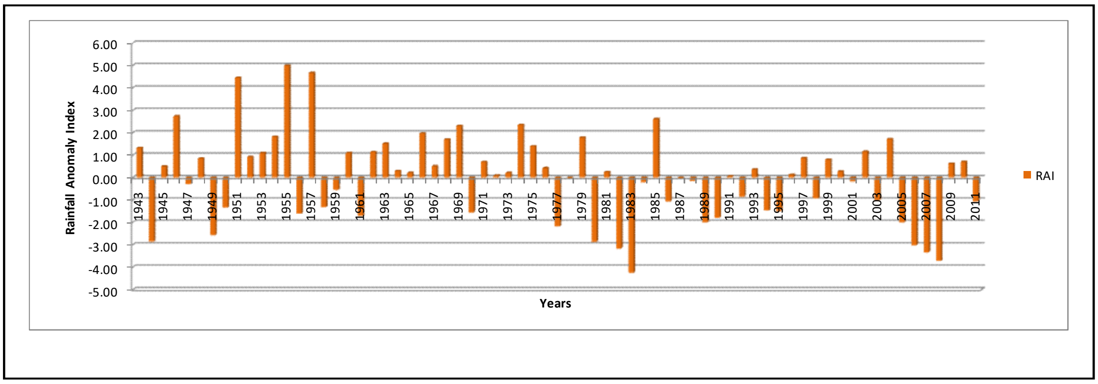


Figure 2: Rainfall Anomaly Index for Kaduna

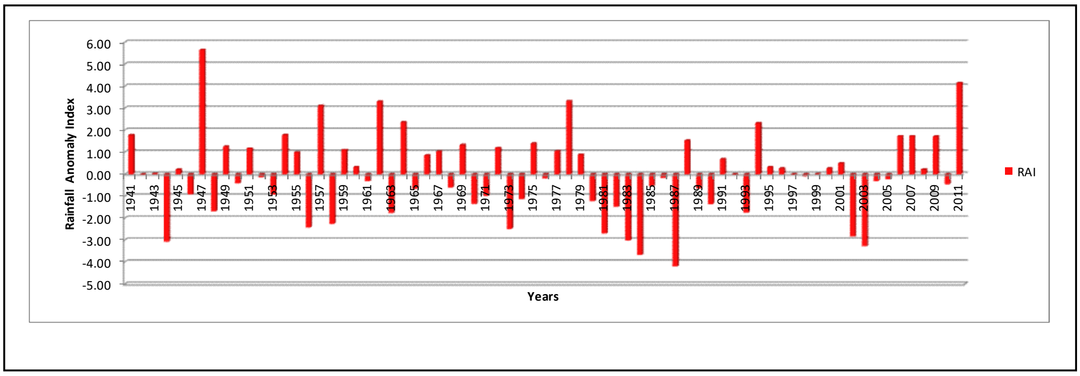


Figure 3: Rainfall Anomaly Index for Minna

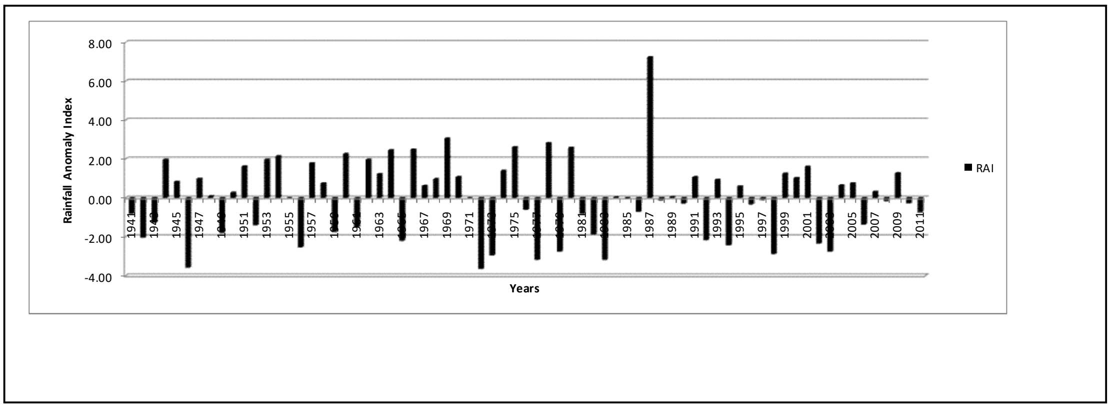


Figure 4: Rainfall Anomaly Index for Bida

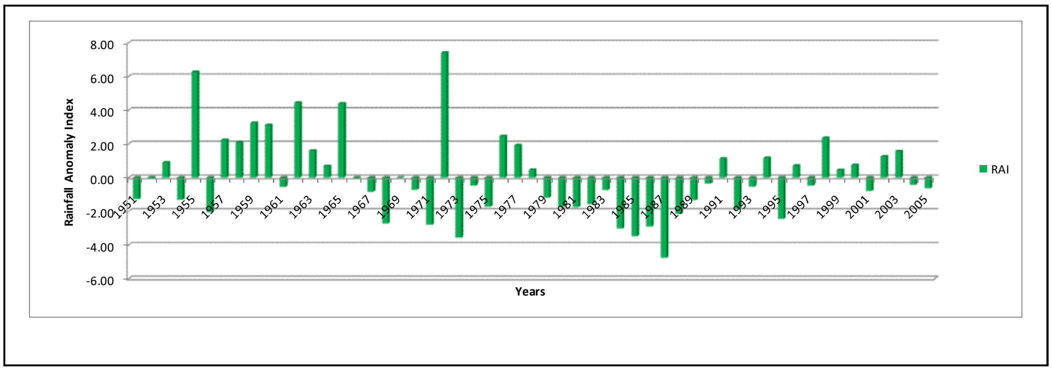


Figure 5: Rainfall Anomaly Index for Sokoto

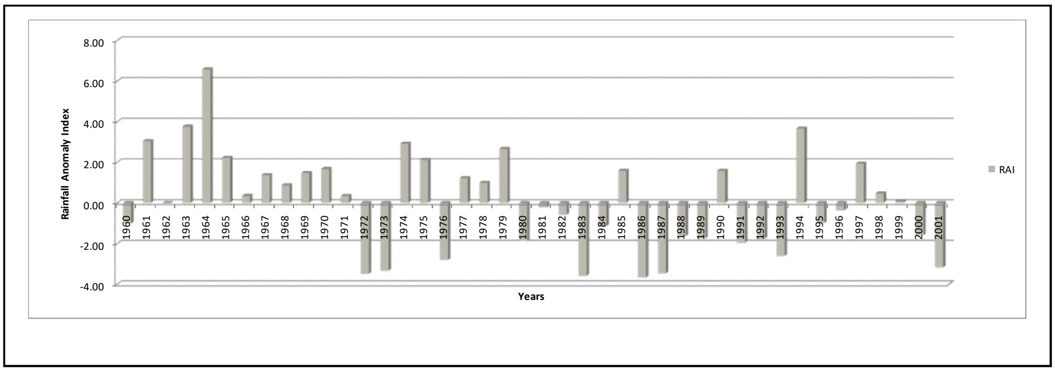


Figure 6: Rainfall Anomaly Index for Nguru

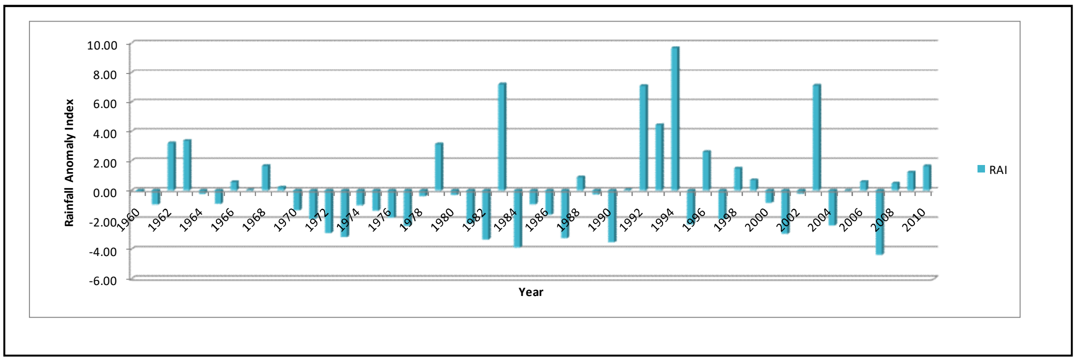


Figure 7: Rainfall Anomaly Index for Gusau

**Drought Frequency**

The results of the computed probabilities of occurrence and return intervals of drought for the study locations are presented in Table 2.

**Table 2:** Drought Probabilities and Recurrence Intervals

| Station | Probability | Recurrence Interval |
|---|---|---|
| Kaduna | 0.44 | 2.27 |
| Minna | 0.52 | 1.92 |
| Bida | 0.46 | 2.17 |
| Sokoto | 0.58 | 1.72 |
| Nguru | 0.5 | 2.00 |
| Gusau | 0.63 | 1.59 |

As shown in Table 2, Kaduna had a drought occurrence probability of 0.44 and a recurrence interval of 2.27 years. The probabilities of drought occurrence for Minna and Bida were 0.52 and 0.46, while the recurrence intervals were 1.92 and 2.17, respectively. For Sokoto, the probability of drought occurrence and recurrence interval was 0.58 and 1.72 years respectively, while for Nguru it was 0.5 and 2 years. For Gusau, the computed probability of occurrence was 0.63 with a return interval of 1.59 years.

**Implications for Water Resources Development**

The recurrence of drought in northern Nigeria has resulted in the construction of many dams of different sizes to serve as a panacea to the incessant problem. From the 1960s till date, several dams have been constructed across northern Nigeria for different purposes mainly irrigation and water supply. With further realization of the need to harness the nation's water resources, especially in the face of the need to conserve water resources as a way of bridging the gap between low rainfall expectations and water resources utilization for sustainable development in northern Nigeria, River Basin Development Authorities (RBDAs) were established in the 1970s. With the establishment of the RBDAs came the construction of more dams and irrigation schemes especially in the north. This was pursuant to the discharge of one of the functions of the RBDAs that includes the construction, operation and maintenance of dams, lakes, polders, wells, irrigation and drainage facilities.
From the 1940s to the 21$^{st}$ century, there has been an upsurge in the number of dams in the country with most of the dams constructed during the sudano-sahelian drought of the

1970s and 1980s. Table 3 shows the number of dams in Nigeria whose years of completion are identifiable.

**Table 3:** Number of Dams in Country with Identifiable Years of Completion

| Scale of Dam | Before 1949 | 1950s | 1960s | 1970s | 1980s | 1990s | After 2000 |
|---|---|---|---|---|---|---|---|
| Small to Medium | 5 | 5 | 12 | 10 | 25 | 5 | 0 |
| Large | 9 | 2 | 5 | 24 | 27 | 7 | 3 |

Within the hydrological areas of the study locations, a number of small, medium and large dams are in existence. As at 1995, there were 160 dams in Nigeria, with 20 located in Hydrological Area 1 in which Sokoto and Gusau belong. There are 32 dams in Hydrological Area 2 where Kaduna, Minna and Bida are located. In Hydrological Area 8 where Nguru is located, 23 dams were in existence (Japan International Agency, 1995). As at 2012, a total of 226 dams (including those under construction) made up of 106 large dams and 120 medium to small sized dams are in existence in Nigeria (Japan International Agency, 2012).

The inventory of dams according to the Project for Review and Update of the Nigerian National Water Resources Master Plan (2012) shows that in Hydrological Area I (Sokoto-Rima Basin) in which Sokoto and Gusau are located, a total of 11 small to medium sized dams and 23 large dams are in existence, while 1 dam is under construction. In Hydrological Area II (Upper Niger River Basin) where Minna, Bida and Kaduna are located, a total of 13 small to medium sized dams and 19 large dams are in existence, while 3 dams are under construction. Within Hydrological Area VIII (Chad Basin) where Nguru is located, there are 5 small to medium sized dams, 24 large dams while 4 dams are under construction.

As a consequence of the recurrence of drought in northern Nigeria and other parts of the Sudano-Sahelian Zone of West Africa through which the River Niger traverses, reduced inflows into the country’s hydroelectric power reservoirs have been recorded. For instance, annual inflows into Kainji hydropower reservoir decreased from $51.5 \times 10^9 m^3$ in 1969 to $17.9 \times 10^9 m^3$ in 1987/1988 as a result of the sahelian drought. This has resulted in the inability of Kainji and Jebba reservoirs to reach their full capacity since the 1980s due to decrease of the black flood from $27 \times 10^9 m^3$ in the 1970s to $18 \times 10^9 m^3$. This decrease is further aggravated by more upstream developments in Mali and Guinea (Oyebande, 1995). Another way in which rainfall deficit has impacted water resources development in northern Nigeria is the establishment of the Gurara inter-basin water transfer scheme. The scheme was embarked upon to increase inflows into the Shiroro hydropower reservoir and boost municipal water supply in Abuja (Jimoh and Ayodeji 2003).

The impact of drought on the agricultural economy of northern Nigeria has also served as one of the impetus to the development of various large and small scale irrigation schemes within the region. From the traditional irrigation systems of the pre-colonial era to the earliest recorded modern irrigation attempts at Kwarre, on the River Niger floodplain in 1908, a number of irrigation projects have been established. Most of the large scale irrigation schemes were established in the 1970s and 1980s to mitigate some of the impacts within the agro-climatic zone. In spite of the establishment of more irrigation projects however, some of the irrigation schemes are bedeviled with a number of technical, management, legislative and institutional challenges, thereby preventing the effective development and utilization of water resources for irrigation development.

**Conclusion and Recommendations**

The recurrence of drought in northern Nigeria represents a source of challenge to the sustainable development of water resources within the region. This situation, therefore, requires the evolution of appropriate infrastructural and institutional measures to improve the reliability of water resources systems and infrastructures to meet future demand under drought conditions. To mitigate as well as reduce the vulnerability of water resources systems and the society to some of the unpalatable consequences of drought, there is a need for water supply planning, demand management and impact minimization.

With regards to water supply planning, there may be need to explore options such as treatment and reuse of waste water, cloud seeding to increase rainfall, inter-basin water transfer, location of potential new sources, monitoring and forecasting and adjustment of legal and institutional framework. Options that can be adopted in the management of water demand include water recycling, adoption of supplementary and deficit irrigation, adoption of water saving irrigation techniques such as drip and sprinkler techniques, provision of incentives to invest in water saving technologies, vulnerability assessment and education of water consumers.

On the minimization of the impact of drought on water resources, a number of options can also be explored. These include the development of early warning systems and drought information systems, cultivation of drought resistant plants, reallocation of water resources based on water quality requirements, development of drought contingency plans and education of the populace to increase their preparedness for drought.

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