AGRICULTURAL AUTOMATION, CLIMATE CHANGE-ACTION AND FOOD SECURITY: GLOBAL ISSUES & LOCAL PERSPECTIVES

Edited by

Eteyen Nyong

Elsie Hamadina

Henrietta Ogan

Christopher Oche Eche

Published By:

Society for Agriculture, Environmental Resources & Management (SAEREM)

First published 2026

SAEREM World

Nigeria

SAEREM BOOK CHAPTERS First Published 2026 ISBN 978-978-60709-7-6

C 2026 Eteyen Nyong

Typeset in Times New Roman

All rights reserved. No part of this book may be reprinted or reproduced or utilized in any form or by any electronic, mechanical, or others means, now, known or hereafter invented including photocopying and recording or in any information storage or retrieved system, without permission in writing from the copyrights owners.

AGRICULTURAL AUTOMATION, CLIMATE CHANGE-ACTION AND FOOD SECURITY (GLOBAL ISSUES & LOCAL PERSPECTIVES)

SAEREM BOOK CHAPTERS First Published 2026 ISBN 978-978-60709-7-6

Printed at: SAEREM

SAEREM BOOK CHAPTERS First Published 2026 ISBN 978-978-60709-7-6

TABLE OF CONTENTS

Preface

Editorial Note

Table of Contents

Acknowledgement

Dedication

Part one: AGRICULTURAL AUTOMATION Chapter One

Chapter One

Organic and Mineral Soil Amendments as Enablers of Climate-Smart Agricultural Automation: Implications for Soil Water Management and Food Security

*Paul Omaye Joseph[1,4], Enya Anari Akpa[2,4], King Ndeari Dedan[3,4],

Chapter Two

Climate Change–Driven Shifts in Plant Pathogen Epidemiology

IVOKE, Michael Anaelechi

Chapter Three

Bridging the Post-Harvest Loss Gap: Modernizing Middle-Mile Logistics to Eliminate Food Loss

Uzoma Uloma Onyewuchi (Ph.D)

SAEREM BOOK CHAPTERS First Published 2026 ISBN 978-978-60709-7-6

Chapter Four

Transforming Agriculture with Smart Technologies: Benefits,Challenges and Implementation Pathways

[1]Igbojionu, Donatus Okwudiri,[2]Igbojionu, Juliet Nnennaya and [3]Anyika, Felicia

Part two: THE CONCEPT OF CLIMATE CHANGE-ACTION

Chapter Five

Impact of Climate Change on Growth in Nigeria.

Tanimu Joseph[1] & Rebecca Yusuf Auta[2]

Chapter Six

Assessment of Conveyance Efficiency and Its Effect on Agricultural Activities in the Falalia Sector of Middle Rima Valley Irrigation Scheme, Goronyo, Nigeria.

***Sadiq Salihu Kumu[1]; Ibrahim Bala[1]; Umar Ibrahim Chonoko[2]; Fiddausi Salihu Kumu[3]**

Chapter Seven

Digital Veterinary Extension and Statistical Modelling for Climate-Resilient Livestock Disease Surveillance in Nigeria

[1]Chidinma Theresa Nwosu[1], Aren Fatandi Peter[2,] Silas Yibarga Gani[3] & Baridanu Hope Mbube[4]

Chapter Eight

Review of Environmental Degradations in Nigeria From 1960 To 2026: Threats, Policy Frameworks, and Strategic Responses

[1,3]Salami, K. D. [2]Iroko, O.A., [4]Pius, Emmanuel Ekomki and [3]Soba, T. M.

SAEREM BOOK CHAPTERS First Published 2026 ISBN 978-978-60709-7-6

Part three: THE CONCEPT OF FOOD SECURITY

Chapter Nine

Musa Paradisiaca (Plantain) Production In A Climate Change Agriculture

Omu, Paul B.

Chapter Ten

Building Climate Resilience in Nigeria's Food Systems: Integrating Adaptation Strategies for Sustainable Food Security:

Chapter Eleven

Snake Gourd as a Neglected and Underutilized Crop for Food Security and Climate Resilience in Southeast Nigeria
Dr. Ogechukwu Anulika Umeh

Chapter Twelve

Climate-Smart Livestock Production: Adaptation, Mitigation and Sustainable Strategies for Resilient Livestock systems

Amaechi, C.I. and Adeyemi, E.A

SAEREM BOOK CHAPTERS First Published 2026 ISBN 978-978-60709-7-6

Preface

This book adopts an exegetical approach as well as a pedagogic model, making it attractive agriculture and environmental economics teachers, professional practitioners and scholars. It is eschews pedantry and lays bars the issues in such clarity that conduces to learning. The book elaborates on contemporaneous Agricultural Automation, Climate Change-Action and Food Security issues of global significance and at the same time, is mindful of local or national perspectives making it appealing both to international and national interests. The book explores the ways in which Agricultural Automation, Climate Change-Action and Food Security issues are and should be presented to increase the public's stock of knowledge, increase awareness about burning issues and empower the scholars and public to engage in the participatory dialogue Agricultural Automation, Climate Change-Action and Food Security necessary in policy making process that will stimulate increase in food production and environmental sustainability. Agricultural Automation, Climate Change-Action and Food Security**:** *Global Issues & Local Perspectives* is organized in three parts. Part One deals with The Concept of Agricultural Automation, Part Two is concerned with The Concept of Climate Change-Action and Part Three deals with the Concept of Food Security

Eteyen Nyong; October 2026

SAEREM BOOK CHAPTERS First Published 2026 ISBN 978-978-60709-7-6

Chapter Six

Assessment of Conveyance Efficiency and Its Effect on Agricultural Activities in the Falalia Sector of Middle Rima Valley Irrigation Scheme, Goronyo, Nigeria.

***Sadiq Salihu Kumu[1]; Ibrahim Bala[1]; Umar Ibrahim Chonoko[2]; Fiddausi Salihu Kumu[3]**

[1]Department of Crop Science, Federal University of Agriculture, Zuru, P.M.B 28, Zuru, Kebbi State, Nigeria.

[2]Department of Agricultural Economics and Extension, Federal University of Agriculture, Zuru, P.M.B 28, Zuru, Kebbi State, Nigeria.

[3]Department of Pure and Applied Chemistry, Abdullahi Fodio University of Science and Technology, Aliero, Kebbi State, Nigeria.

*Corresponding author: abubakrkumu@gmail.com; sskumu.crp@fuaz.edu.ng;

TABLE OF CONTENTS

Title

Abstract

Keywords

1.0 INTRODUCTION

1.1 Background

1.2 Irrigation in Nigeria and the Middle Rima Valley Irrigation Scheme

1.3 Problem statement

1.4 objectives

2.0 MATERIALS AND METHODS

2.1 Study area and scheme description

2.2 Operation and layout of the Falalia sector

2.3 Status of the conveyance structures

SAEREM BOOK CHAPTERS First Published 2026 ISBN 978-978-60709-7-6

2.4 Flow measurement and computation of conveyance efficiency

2.5 Questionnaire survey and data analysis

3.0 RESULTS AND DISCUSSION

3.1 Flow measurement

3.2 Conveyance loss and efficiency

3.3 Effect on agricultural activities

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusions

4.2 Recommendations

REFERENCES

1. INTRODUCTION

1.1 Background

Water is the most critical input for sustainable food production. In many parts of the world, the amount and duration of rainfall are insufficient to meet crop water requirements, making irrigation the only viable means of year-round cultivation. Irrigation is the artificial application of water to crops to ensure adequate soil moisture for growth, provide insurance against short-duration drought, soften tillage pans, cool the soil and atmosphere, and leach harmful salts (Ali, A., Hussain, T., & Zahid, A., 2025).

SAEREM BOOK CHAPTERS First Published 2026 ISBN 978-978-60709-7-6

Irrigated agriculture accounts for about 70% of total freshwater withdrawals (Ingrao, C., Strippoli, R., Lagioia, G., & Huisingh, D., 2023) and is increasingly required to produce more food from a limited land area using less water (Rosa Lorenzo., 2022). This pressure is driven by climate variability, population growth, and competition for water from municipal and industrial users. As available water resources become scarce, more emphasis is placed on the efficient use of water for maximum economic return and water-resource sustainability (Alamanos Angelos, 2021). The challenge for irrigation is therefore to produce more with less water. An irrigation system comprises a source, a reservoir or pumping station, a conveyance system, a distribution system, a field application system and a drainage system; its purpose is to deliver water in the specified quantity for plant use while minimising losses as far as possible.

Dams and reservoirs, especially in arid and semi-arid regions, supply water for domestic, agricultural, industrial and hydropower needs (Barbosa Llauet O., 2022; Polanski, M.,& Wiatkowski, M., 2023; Wendt, D. E., Bloomfield, J. P., Van Loon, A. F., Garcia, M., Heudorfer, B., Larsen, J., & Hannah, D. M., 2021). They are critical for livelihoods and development, enhancing surface water availability, food production, energy supply and flood control in developing countries (Ibrahim Aliyu Hassan, 2026).

The Food and Agriculture Organization (FAO) estimates that the efficiency of most irrigation schemes in developing countries remains below 50%, largely because of losses in conveyance and distribution. The overall efficiency of an irrigation system is the product of the conveyance, distribution and field application efficiencies. Conveyance efficiency, the focus of this study, is the proportion of water diverted at the source that reaches the distribution points. It is expressed as $E_c = (Q_{downstream}/Q_{upstream}) \times 100$, where Q is discharge. Losses ($100 - E_c$) occur through seepage, evaporation, overtopping, siltation and operational spillage.

The nature and magnitude of conveyance losses depend on canal lining, geometry, soil properties, water depth, flow velocity, groundwater level, vegetation and maintenance status. Unlined earthen canals are particularly prone to seepage losses ranging from 0.1 to 1.0 $m^3/day/m^2$ according to the global synthesis by Lund Ahmad A., 2024). Recent field studies provide clear evidence. In Pakistan's Thal canal, Khan Faridullah et. al. (2026) monitored six years of data and found seepage losses of 5% in precast concrete (PCC) lined, 13% in brick-lined and 22% in unlined canals; they also demonstrated that data-driven models such as CatBoost can predict seepage with $R^2 = 0.97$. In Uzbekistan, where 75% of canals remain earthen, Arifjanov Aybek et al (2022) reported an average conveyance efficiency of only 63% owing to vegetation, erosion and sedimentation, and Sultonov, Z & Pant, H.K., (2023) linked this low efficiency to increasing

water scarcity in the Aral Sea basin. In the Hetao Irrigation District of China, Mao Wei et al (2024) assessed spatial and temporal seepage losses in large canal systems and showed that seepage is most sensitive to surface water level and bed permeability, and that every increase of 100,000 m^2 in lining area below 1 million m^2 improves the reduction factor by 5.8%. These studies underscore a global consensus: lining improves efficiency, but without maintenance the efficiency deteriorates rapidly as weed growth and siltation increase hydraulic resistance and wetted perimeter. Evaluating conveyance efficiency identifies the nature of water loss and the type of improvement needed in the system, and is a prerequisite for the proper use of irrigation water.

1.2 Irrigation in Nigeria and the Middle Rima Valley Irrigation Scheme

Nigeria lies between longitudes 3–15°E and latitudes 4–14°N, bordered by the Republic of Niger, Cameroon, the Republic of Benin and the Gulf of Guinea to the north, east, west and south respectively, with a total land area of about 923,300 square kilometres (Shiru, M. S., Chung, E. S., & Sa'adi, Z., 2025). By virtue of its geographical location, climate and population, water resources are of critical importance to all sectors of the economy, which makes optimal utilisation of this scarce resource imperative. From the 1980s, the Federal Government invested heavily in large-scale irrigation schemes to address rural poverty and food insecurity. The Water Resources Act of 1993 places water in the exclusive domain of the Federal Government for centralized management and control, and provides for water to be protected, utilised, developed, conserved, managed and controlled sustainably; in practice, however, many entities of authority still exist.

One of the flagship projects is the Middle Rima Valley Irrigation Scheme (MRVI), centred on the Goronyo Dam. The dam is located about 90 km north-east of Sokoto town at latitude 13°N and longitude 5°E. It was constructed by Messrs Impresit Bakalori Nigeria Limited from May 1984 and commissioned in 1992. It enables irrigation, flood control and year-round farming by storing water, and supports livestock and food security (Ogilvie, A., Poussin, J. C., Bader, J. C., Bayo, F., Bodian, A., Dacosta, H., & Sambou, S., 2020; Eduvie Martin O., & Oseke Francis I., 2021; Wulder, M. A., Roy, D. P., Radeloff, V. C., Loveland, T. R., Anderson, M. C., Johnson, D. M., ... & Cook, B. D., 2022). It is the second largest man-made dam in Nigeria after Tiga Dam, with a surface area of 200 km^2 and a full storage capacity of 942 million cubic metres at 288 metres above sea level (Eduvie and Oseke, 2021; Martin, O. E., & Francis, O., 2022). The dam is fed by the rivers Gajari, Busuru and Maradi from the Republic of Niger, and the river system extends for about 500 km to Yelwa Yauri in Kebbi State, where the River Rima empties into the River Niger.

SAEREM BOOK CHAPTERS First Published 2026 ISBN 978-978-60709-7-6

The scheme is divided into two phases. Phase 1 (left bank) comprises the Falalia sector, with 736 hectares of net irrigable land, a main canal of 5881 m, 10 distributary canals, 53 field canals and 11 blocks. Phase 2 (right bank) covers 4,333 hectares gross in five sectors: Takakume, Mai-Iyali, Gidan Salihu, Tsi-tse and Tuluski. The Falalia sector operates by gravity through a butterfly valve system. The Falalia main canal (FMC) is concrete-lined and trapezoidal, and is equipped with distributary turnouts (DTO) of 200 litres per second and 100 litres per second depending on block size, cross-regulators, crossing culverts and division boxes. The distributary canals are clay-lined, while the field canals are laterite-lined. Water is controlled from the headwork through emergency spillways, radial gates and sludge gates, and at field level farmers use siphon tubes. Despite this infrastructure, the operational performance of the conveyance system has not been quantitatively assessed in recent years using standard hydraulic methods.

Agriculture remains a primary economic activity and employs more than 50% of the population of developing countries (Pawlak, K., & Kołodziejczak, M. 2020). Farmers in the MRVI produce enough food for their families and sell the surplus to local communities and outside markets. Irrigation also allows higher-value crops, higher yields and more intensive cultivation, which provide a higher, less risky and more continuous level of rural employment and income for both farmers and landless labour (Giller, K. E., Delaune, T., Silva, J. V., Descheemaeker, K., Van De Ven, G., Schut, A. G., & Van Ittersum, M. K. (2021). In addition, land owners benefit from increased land values, which often enhance their access to credit, social standing and empowerment. The scheme therefore improves productivity, employment and income, diversifies rural livelihoods by expanding the non-farm labour market, and provides water for multiple uses (domestic and industrial), thereby improving the socio-economic standard of the locality and the nation.

1.3 Problem statement

As noted by Ali et al (2025), wastage of irrigation water affects not only agriculture but also domestic and industrial uses, and its conservation requires identification of losses at critical points through discharge measurement. In the MRVI, water allocation problems persist. Farmers at the tail ends of the Falalia sector have reported inadequate water, especially in the dry season when irrigation is limited to three days per week, compared with daily irrigation of rice in the rainy season. The main canal, although concrete-lined, suffers from siltation caused by soil deposits, pebbles and other materials. The distributary canals, being clay-lined, have lost their trapezoidal shape and become parabolic owing to erosion and weed infestation.

A heavy presence of aquatic weeds on the water surface and lining increases roughness, reduces velocity, and makes flow measurement and seepage estimation difficult.

The problem is threefold. First, there are no recent field-measured data on conveyance efficiency for the Falalia sector using the velocity-area float method with appropriate correction coefficients (0.90 for concrete and 0.80 for earthen canals, as recommended by Chow (1959). Second, the impact of these hydraulic losses on agricultural activities such as crop choice, irrigation method and farmer perception has not been linked empirically. Third, although the global literature from 2020 to 2026 shows rapid advances in understanding seepage, Nigerian schemes such as the MRVI remain under-represented. Without such an assessment, it is difficult for the Sokoto Rima River Basin Development Authority (SRRBDA) to prioritise maintenance funds between desilting, weed control and re-lining. This study therefore asks what the present condition of the conveyance structures in the Falalia sector is, what the quantitative conveyance losses and efficiencies are, and how these relate to agricultural production. Improving conveyance efficiency is a climate-smart action because it is among the least costly ways of increasing water productivity without developing new water sources.

1.4 Objectives

The overall objective of this study was to assess the operational performance of the conveyance system of the Falalia sector of the MRVI. The specific objectives were:

(i) to determine the present condition of the irrigation conveyance structures in the Falalia sector;

(ii) to assess the conveyance losses and efficiencies of selected main and distributary canals using the velocity-area approach; and

(iii) to assess the impact of the identified losses and efficiencies on agricultural activities in the area.

The study provides recent field-measured data on conveyance efficiency in the Falalia sector that the SRRBDA can use to prioritise desilting and weed control. It also relates the tail-end water shortage reported by farmers to the maintenance status of the canals.

2. MATERIALS AND METHODS

2.1 Study area and scheme description

The study was carried out on the main and distributary canals of the Falalia sector of the Goronyo Dam, about 90 km north-east of Sokoto town, Nigeria (latitude 13°N, longitude 5°E). The dam was constructed across the River Rima by Messrs Impresit Bakalori Nigeria Limited from May 1984 and is a key structure in the water-resources development of the Sokoto-Rima River Basin Development Authority (SRRBDA) for the MRVI and fadama irrigation. The reservoir extends up to 20 km in length and 10 km in width and is impounded by three embankments (main, secondary and saddle dykes) that form a lake of 200 km^2, with irrigation potential for 81,000 hectares (Ibrahim A.H., 2026). The dam has a storage capacity of 942 million cubic metres.

The main canal is concrete-lined. Clay lining was provided for porous portions of the distributary canals, field canals were provided along the main and distributary canals, and field tracks run along the field canals. Field, lateral and collector drains were constructed to dispose of excess water and runoff outside the irrigation area. Phase 1 (the left-bank scheme, Falalia sector) comprises 736 hectares of net irrigable land for year-round cultivation, a headwork and a main canal of 5881 m. Phase 2 (the right-bank scheme) comprises 4333 hectares gross, covering the Rima Main Canal (RMC), a headwork and five sectors (Takakume, Mai-Iyali, Gidan Salihu, Tsi-tse and Tuluski), of which only the first two were newly functioning at the time of this research.

2.2 Operation and layout of the Falalia sector

The Falalia sector draws its water from the Goronyo Dam through the Falalia headwork. The Falalia main canal (FMC) is concrete-lined, 5881 m long, and is fitted with distributary turnouts and cross-regulators to distribute water and control heads in the eleven irrigation blocks. The sector is operated by setting the butterfly valve to the gauge that releases the required discharge into the sector, and by manipulating the gates at the interface for daily control. Blocks are regulated through distributary turnout gates of 200 litres per second and 100 litres per second, depending on block size and the amount required at a particular time. Field canals are controlled through field turnout gates, and farmers use siphon tubes to divert water from the field canals to individual plots. Operation is by gravity. In the dry season irrigation is limited to three days per week, whereas it is daily in the rainy season because of the cultivation of crops with high water demand, such as rice.

SAEREM BOOK CHAPTERS First Published 2026 ISBN 978-978-60709-7-6

The sector consists of one main canal, eleven blocks with fifty-three field canals, and ten distributary canals. The intake structure directs water from the source into the system; the conveyance system transports water from the intake to the field ditches and irrigated fields; and the drainage system removes excess water from the fields. The main canal must retain the designed water levels along its entire 5881 m length, and it runs through terrain whose slope is generally different from, and smaller than, that of the canal.

2.3 Status of the conveyance structures

The Falalia main canal is concrete-lined and trapezoidal, while the distributary canals are clay-lined. Major maintenance work is carried out periodically on the main canal, and the main hindrance to efficient conveyance there is siltation caused by soil deposits, pebbles and other materials. The clay-lined distributary canals have mostly lost their trapezoidal shape and are more or less parabolic. Heavy weed infestation is the major problem in these canals, making flow measurement difficult and the estimation of seepage losses uncertain.

2.4 Flow measurement and computation of conveyance efficiency

Discharge was measured by the velocity-area (float) method. A floating object (a plastic bottle) was released at the upstream end of a measured length of canal, and the time taken to travel to the downstream end was recorded. The procedure was repeated three times and the mean travel time was used to compute the surface velocity ($V_s = L/t$). The cross-sectional area was obtained from the bottom width (B_1), top width (B_2) and average depth (d) measured with a measuring tape. Surface velocity was converted to mean velocity using a correction factor of 0.90 for the concrete-lined main canal and 0.80 for the earthen distributary canal (Chow, 1959):

$$V = k \times V_s \quad (1)$$

$$A = ½ (B_1 + B_2)\, d \quad (2)$$

$$Q = A \times V \quad (3)$$

$$\Delta Q = Q_{upstream} - Q_{downstream} \quad (4)$$

$$E_c = (Q_{downstream}/Q_{upstream}) \times 100 \quad (5)$$

Three sections were measured on the main canal (CH1+150, CH1+250 and CH1+350). The first was located in the upper section of the canal, where the concrete-lined channel is uniform and trapezoidal, making

the site suitable for flow measurement; the second and third sections were located downstream at CH1+250 and CH1+350. Two sections were measured on the distributary canal using the same procedure, although readings were difficult to take because the clay-lined channel was heavily infested with weeds. Conveyance loss and efficiency were computed between successive sections, and the cumulative efficiency of the main-canal reach was obtained as the product of the efficiencies of the two reaches.

The following factors were considered in selecting and placing the measurement sections (Lund A.A.R. in Ancid, 2003): (i) the flow in the section should be steady and uniform; (ii) there should be no change in water level during measurement; (iii) there should be no flow into or out of the segment from external sources; (iv) there should be no disruption in the cross-sectional geometry of the segment and nothing to obstruct the flow; and (v) the length of the segment should be sufficient for the measurement of conveyance loss.

2.5 Questionnaire survey and data analysis

Data were collected from primary and secondary sources. Primary data were obtained through a general field survey and structured questionnaires, which comprised mainly close-ended questions, with open-ended questions used where the possible responses were not known in advance. Secondary data were obtained from textbooks, journals, previous related literature, papers, presentations and written reports from the MRVI station. Simple random sampling was adopted: two farmers were selected at random from each of the eleven blocks of the Falalia sector, giving a total of twenty-two respondents. The questionnaires were administered through an interview schedule. The data were summarised using descriptive statistics (frequencies and percentages) and presented in tables.

3. RESULTS AND DISCUSSION

3.1 Flow measurement

Flow measurements were made at three sections of the Falalia main canal and two sections of the distributary canal. The measured geometry, mean float travel times, velocities and computed discharges are presented in Tables 1 and 2.

SAEREM BOOK CHAPTERS First Published 2026 ISBN 978-978-60709-7-6

Table 1. Computed conveyance efficiency of the Falalia main canal (FMC)

Canal section	Bottom width (m)	Top width (m)	Depth (m)	Area (m^2)	Length (m)	Time taken (sec)	Velocity (m/sec)	Discharge (m^3/s)	Conveyance efficiency (%)
CH1+150	1.42	5.40	1.22	4.16	10.20	50.57	0.18	0.749	–
CH1+250	0.85	4.80	1.28	3.62	16.00	88.68	1.62	0.5184	69.21
CH1+350	0.41	4.36	0.84	2.00	16.00	86.27	0.171	0.342	65.97

Source: Field survey 2025

Table 2. Computed conveyance efficiency of the Falalia distributary canal (FDC)

Canal section	Bottom width (m)	Top width (m)	Depth (m)	Area (m^2)	Length (m)	Time taken (sec)	Velocity (m/sec)	Discharge (m^3/s)	Conveyance efficiency (%)
Section 1	1.24	3.87	0.60	2.69	2.00	24.60	0.064	0.098	–
Section 2	1.15	3.60	0.40	0.95	5.00	64.50	0.064	0.061	62.24

Source: Field survey 2025

In the Falalia main canal, discharge decreased progressively from the first section to the sections downstream (Table 1). The water level did not change during measurement; the decrease is associated instead with silt deposition of varying degree in the canal sections. Velocity was nearly constant between sections (0.18–1.62 m/s), so the decline in computed discharge is governed mainly by the reduction in flow area, from 4.16 m^2 at CH1+150 to 3.62 m^2 at CH1+250 and 2.00 m^2 at CH1+350, and by differences in the lengths of the measured sections. Part of this reduction reflects the tapering of the canal by design and part reflects siltation, as the bottom width falls from 1.42 m to 0.41 m. The computed differences in discharge should therefore be interpreted as apparent conveyance losses, which may also include leakage and uncertainty inherent in single-day float measurements over short reaches.

The distributary canal sections took longer to cover even shorter distances than the main-canal sections, resulting in low velocities (about 0.064 m/s). This is attributed to the heavy presence of aquatic weeds within and around the lining of the channel and on the water surface, which increases roughness and reduces the flow rate (Table 2).

3.2 Conveyance loss and efficiency

Conveyance loss was computed by subtracting the discharge at a section from that at the preceding section. In the main canal, the loss between Q_1 and Q_2 was 0.2306 m^3/s and that between Q_2 and Q_3 was 0.1764 m^3/s; in the distributary canal, the loss between Q_1 and Q_2 was 0.037 m^3/s. The conveyance efficiencies are presented in Tables 1 and 2.

The efficiency of the main canal was 69.21% between Sections 1 and 2 (a loss of 30.79%) and 65.97% between Sections 2 and 3 (a loss of 34.03%), giving a cumulative efficiency of 45.66% over the reach studied. The efficiency of the distributary canal was 62.24%, a loss of 37.76%. In absolute terms the main canal lost more water than the distributary canal because it carries a larger discharge, but proportionally the losses were greater in the distributary canal. The cumulative efficiency of the main-canal reach is below the 50% level that FAO reports for most irrigation schemes in developing countries, and the efficiency of the distributary canal is almost at the 63% reported for earthen canals in Uzbekistan by Arifjanov et al (2022). The losses in the concrete-lined main canal were also much higher than the 5% seepage loss reported for precast concrete-lined canals by Khan et al (2024), which suggests that siltation, canal geometry and operational factors, rather than seepage alone, contribute to the losses in the Falalia main canal.

The conveyance structures of the main canal can therefore be described as moderately efficient in the upper reach, with efficiency declining downstream, while the distributary canal is in poor condition. This agrees with the IWASRI report (Ul Hasan, F., Dare, L., & Sinclair, D., 2025 in IWASRI, 2004) on studies carried out by the Water Course Monitoring and Evaluating Directorate of WAPDA, in which losses were measured on 26 water courses, of which 10 were lined (brick-lined) and 16 were unlined; on the lined water courses, a net increase of 12–14% in conveyance efficiency was found from head to tail reach. The overall efficiency of an irrigation system relates to the effective utilisation of irrigation water through the various stages of water routing from the source to the receptors (Amer Mayie, 2021), and the quantity of losses depends largely on the quality of operation and maintenance.

3.3 Effect on agricultural activities

The status of the conveyance structures is a major factor in the efficient transport and utilisation of irrigation water, although it is not the only determining factor. Information on the agricultural activities of the farmers in the scheme, based on their responses, is presented in Tables 3 to 10.

SAEREM BOOK CHAPTERS First Published 2026 ISBN 978-978-60709-7-6

Table 3. Age distribution of farmers

Age range (years)	Frequency	Percentage (%)
18–25	2	9.1
26–33	7	31.8
34–41	2	9.1
42–49	2	9.1
Above 49	9	40.9
Total	**22**	**100**

Source: Field survey 2025

Table 3 shows that the majority of the farmers (40.9%) were above 49 years of age, followed by those aged 26–33 years (31.8%). Young adults (18–25 years) and those aged 34–41 and 42–49 years each accounted for only 9.1% of the respondents.

Table 4. Major crop production

Crop type	Frequency	Percentage (%)
Rice	19	86.4
Cereals	–	–
Onions	3	13.6
Vegetables	–	–
Others	–	–
Total	**22**	**100**

Source: Field survey 2025

Rice was the major crop cultivated in the irrigation area (86.4%), with only a few farmers (13.6%) producing onions (Table 4). The dominance of rice, a crop with high water demand, makes the reliable delivery of water through the conveyance system particularly important.

SAEREM BOOK CHAPTERS First Published 2026 ISBN 978-978-60709-7-6

Table 5. Major source of water

Source of water	Frequency	Percentage (%)
Irrigation system only	–	–
Irrigation and rainfall	22	100
Rivers and streams	–	–
Shallow dug-outs	–	–
Others	–	–
Total	**22**	**100**

Source: Field survey 2025

All the farmers indicated that the irrigation system and rainfall were their sources of water (Table 5).

Table 6. Type of irrigation method adopted

Method of irrigation	Frequency	Percentage (%)
Drip	–	–
Basin	4	18.2
Border	18	81.8
Furrow	–	–
Total	**22**	**100**

Source: Field survey 2025

Two irrigation methods were adopted in the study area (Table 6): the border method, used by almost all the farmers (81.8%), and the basin method (18.2%). None of the farmers used drip or furrow irrigation.

Table 7. Level of government involvement in agricultural activities

Rating	Frequency	Percentage (%)
Excellent	–	–

Rating	Frequency	Percentage (%)
Satisfactory	11	50.0
Average	2	9.1
Low	9	40.9
Very low	–	–
Total	**22**	**100**

Source: Field survey 2025

Half of the farmers (50.0%) rated government involvement in agricultural activities as satisfactory, 9.1% rated it as average, and 40.9% rated it as low (Table 7).

Table 8. Training and support services needed

Type of support	Frequency	Percentage (%)
Maintenance	11	50.0
Organisation and management	9	40.9
Increased capacity	2	9.1
Others	–	–
Total	**22**	**100**

Source: Field survey 2025

Half of the farmers (50.0%) considered maintenance the service most needed in the system, 40.9% considered organisation and management most needed, and only 9.1% gave priority to increased capacity of the system (Table 8).

Table 9. Factors militating against irrigation efficiency

Identified challenges	Frequency	Percentage (%)
Water shortage	–	–

Identified challenges	Frequency	Percentage (%)
Lack of inputs	–	–
Poor facilities	3	13.6
Poor maintenance	19	86.4
Others	–	–
Total	**22**	**100**

Source: Field survey 2025

The great majority of the farmers (86.4%) identified poor maintenance of the system as the major factor affecting irrigation efficiency and agricultural production, while the remaining 13.6% named poor facilities (Table 9). This is consistent with the field observations of siltation in the main canal and weed infestation in the distributary canal.

Table 10. Farmers' rating of irrigation efficiency

Rating	Frequency	Percentage (%)
Excellent	3	13.6
Satisfactory	14	63.6
Average	5	22.7
Low	–	–
Very low	–	–
Total	**22**	**100**

Source: Field survey 2025

Most farmers (63.6%) rated the performance of the system as satisfactory, 13.6% rated it as excellent, and 22.7% rated it as average (Table 10). Farmers' ratings reflect the water they receive at their plots, and do not necessarily capture the hydraulic losses measured in the canals; the contrast between these ratings and the low measured efficiency of the distributary canal indicates that the system continues to support production but with considerable room for improvement. Because the sample was small (22 farmers) and

the analysis descriptive, the relationship between conveyance losses and agricultural productivity could not be tested statistically and should be investigated in further work.

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The results show that the discharge available to farmers depends largely on the efficiency of the conveyance structures and of the other components of the irrigation system. In the Falalia main canal, conveyance efficiency was 77.74% between the first two sections but fell to 56.81% between the second and third sections, with a cumulative efficiency of 44.2%; the decline was associated mainly with siltation and the reduction in flow area. In the distributary canal, efficiency was only 33.61%, as a result of heavy weed infestation and loss of the trapezoidal shape. The conveyance structures are thus moderately efficient in the upper reach of the main canal but deteriorate downstream and in the distributary canal.

Rice production under border irrigation dominates in the sector, and 86.4% of the farmers identified poor maintenance as the major problem. Although the system still supports farming and most farmers rated its performance as satisfactory or excellent, the measured losses show that constant maintenance is needed. The study covered only part of the scheme, since not all sectors are functioning, and is intended to serve as a foundation and guide for further research.

4.2 Recommendations

Based on the findings, the following recommendations are made:

1. Preventive and corrective maintenance, including regular desilting of the main canal and weed control in the distributary canals, should be carried out to improve system delivery and reduce wastage.
2. Government and other stakeholders should provide the funding and training needed for maintenance and for the organisation and management of the scheme.
3. A more efficient record-keeping system should be adopted to serve as a reference and to forecast future trends.
4. Further studies covering more sections, seasons and sectors, and including direct measurement of seepage, should be undertaken to complement the present assessment.

SAEREM BOOK CHAPTERS First Published 2026 ISBN 978-978-60709-7-6

REFERENCES

Alamanos, A. (2021). Sustainable water resources management under water-scarce and limited-data conditions. Central Asian Journal of Water Research, 7(2), 1-19.

Ali, A., Hussain, T., & Zahid, A. (2025). Smart irrigation technologies and prospects for enhancing water use efficiency for sustainable agriculture. AgriEngineering, 7(4), 106.

Ibrahim, A. H. Spatio Temporal Assessment of Goronyo Dam in Sokoto State.

Amer, M. (2021). Effect of Different Types of Emitters and Irrigation Intervals on the Productivity and Quality of Squash Under the Nile Delta Conditions. Misr Journal of Agricultural Engineering.

Arifjanov, A., Allayorov, D., Khazratov, A., Ibragimova, Z., Bakhromova, D., & Makhmudov, B. (2022). Effective Design Approaches for Lined Canals: Case Study of the North Fergana Main Canal.

Barbosa Llauet, O. (2022). Mitigation of floods and droughts in tropical wet & dry climate regions through Water Resource Management. A case study in Lake Tana, Ethiopia.

Eduvie, M. O., & Oseke, I. F. (2021). Cumulative impacts of climate change variability around the Goronyo Dam in the Iullemmeden basin, northwest Nigeria. In Climate Change and Water Resources in Africa: Perspectives and Solutions Towards an Imminent Water Crisis (pp. 171-192). Cham: Springer International Publishing.

Giller, K. E., Delaune, T., Silva, J. V., Descheemaeker, K., Van De Ven, G., Schut, A. G., ... & van Ittersum, M. K. (2021). The future of farming: Who will produce our food? Giller KE et al. Food security, 13(5), 1073-1099.

Ingrao, C., Strippoli, R., Lagioia, G., & Huisingh, D. (2023). Water scarcity in agriculture: An overview of causes, impacts and approaches for reducing the risks. Heliyon, 9(8).

Khan, F., Gabriel, H. F., & Akhtar, H. (2026). Comparative Evaluation of Empirical and Data-Driven Techniques for Estimating Seepage Losses in Irrigation Canals. *Irrigation and Drainage*.

Lund, A. A. R. (2024). *Assessing Irrigation Canal Seepage Reduction Using Polymer Sealants* (Doctoral dissertation, Colorado State University).

SAEREM BOOK CHAPTERS First Published 2026 ISBN 978-978-60709-7-6

Mao, W., Zhu, Y., Huang, S., Han, X., Sun, G., Ye, M., & Yang, J. (2024). Assessment of spatial and temporal seepage losses in large canal systems under current and future water-saving conditions: A case study in the Hetao Irrigation District, China. *Agricultural Water Management*, *291*, 108615.

Martin, O. E., & Francis, O. (2022). Cumulative Pressure from Climate Change: Case Study of the Goronyo Dam, Iullemmeden Basin, Northwest Nigeria. Water Resources, 32, 26-46.

Ogilvie, A., Poussin, J. C., Bader, J. C., Bayo, F., Bodian, A., Dacosta, H., ... & Sambou, S. (2020). Combining multi-sensor satellite imagery to improve long-term monitoring of temporary surface water bodies in the Senegal river floodplain. Remote Sensing, 12(19), 3157.

Pawlak, K., & Kołodziejczak, M. (2020). The role of agriculture in ensuring food security in developing countries: Considerations in the context of the problem of sustainable food production. Sustainability, 12(13), 5488.

Połomski, M., & Wiatkowski, M. (2023). Impounding reservoirs, benefits and risks: A review of environmental and technical aspects of construction and operation. Sustainability, 15(22), 16020.

Rosa, L. (2022). Adapting agriculture to climate change via sustainable irrigation: biophysical potentials and feedbacks. Environmental Research Letters, 17(6), 063008.

Shiru, M. S., Chung, E. S., & Sa'adi, Z. (2025). Performance assessment of satellite precipitation products over Nigeria: a compromise programming approach. Earth Systems and Environment, 9(4), 3289-3310.

Sultonov, Z., & Pant, H. K. (2023). Potential impacts of climate change on water management in the Aral Sea basin. *Water Resources Management*, *37*(14), 5743-5757.

Te Chow, V. (1959). *Open channel hydraulics*.

ul Hasan, F., Dare, L., & Sinclair, D. (2025). Governing groundwater in the Indus Basin: Barriers to effective groundwater management and pathways for reform. *Environmental Science & Policy*, *173*, 104247.

Wendt, D. E., Bloomfield, J. P., Van Loon, A. F., Garcia, M., Heudorfer, B., Larsen, J., & Hannah, D. M. (2021). Evaluating integrated water management strategies to inform hydrological drought mitigation. Natural Hazards and Earth System Sciences, 21(10), 3113-3139.

Wulder, M. A., Roy, D. P., Radeloff, V. C., Loveland, T. R., Anderson, M. C., Johnson, D. M., ... & Cook, B. D. (2022). Fifty years of Landsat science and impacts. *Remote Sensing of Environment*, *280*, 113195.

SAEREM BOOK CHAPTERS First Published 2026 ISBN 978-978-60709-7-6