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EFFECT OF SEDIMENT TRANSPORT ON IRRIGATION EFFICIENCY: A REVIEW

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Abstract: This review examines the influence of sediment transport on the efficiency of irrigation systems, with emphasis on its sources, mechanisms, and impacts on water distribution and infrastructure. Sediment originating from erosion, weathering, and land –use practices interferes with water flow, reduces conveyance efficiency, and clogs irrigation infrastructure such as canals, pipes, plus nozzles. The accumulation of sediments can also degrade water quality, reduce infiltration rates, and impair crop productivity. Various mitigation strategies including improved catchment management, sediment exclusion structures, and erosion control measures are discussed. In addition, the review highlights integrated management approaches involving watershed conservation, sediment modeling, and institutional support to ensure the sustainability of irrigation schemes. Lastly, effective sediment control is essential to optimize water use, reduce maintenance costs, and enhance agricultural productivity in sediment prone areas.

Keywords: Irrigation systems, sediment transport, mitigation, waterways

INTRODUCTION

Efficient irrigation is fundamental to agricultural productivity and water conservation. However, sediment transport in irrigation systems presents a significant challenge. Sediments originate from watershed erosion, unlined canals, and agricultural activities. When carried by irrigation water, they influence flow dynamics, infrastructure functionality, and water distribution, potentially reducing the efficiency and longevity of irrigation schemes. Hence, Irrigation is the application of water to the land to eradicate moisture limitation in crop production (Onwualu *et al*., 2006). The practice includes the development of the water supply, the conveyance system, the method of application and the necessary management to achieve the intended purpose. The need for irrigation arises because rainfall frequently does not occur at the right time or in the right amount to satisfy crop needs (Obineche, 2018). Irrigation can be classified into four main methods namely surface, subsurface, sprinkler and drip. Onwualu *et al*., (2006) reported that there are three commonly used methods, surface, sprinkler, and drip irrigation. Surface irrigation is the application of water by gravity flow to the surface of the field. Either the entire field is flooded (basin irrigation) or the water is fed into small channels (furrows) or strips of land (borders). Basins are flat areas of land, surrounded by low bunds. Furrows are small channels, which carry water down the land slope between the crop rows. Water infiltrates into the soil as it moves along the slope. The crop is usually grown on the ridges between the furrows. This method is suitable for all row crops and for crops that cannot stand in water for long periods. Irrigation water flows from the field channel into the furrows by opening up the bank of the channel, or by means of siphons or spiles. Borders are long, sloping strips of land separated by bunds. They are sometimes called border strips. Irrigation water can be fed to the border in several ways:

- opening up the channel bank,
- using small outlets or gates, or
- by means of siphons or spiles.

Sprinkler is a method of applying irrigation water which is similar to natural rainfall. Water is distributed through a system of pipes usually by pumping. (Obineche *et al*. 2021) posited that, drip irrigation minimizes the activity of soil as a storage reservoir for water, by a systematic injection of daily soil moisture requirement to the root zone of each plant, which results in a balance soil matric potential in the rhizosphere thereby relieving plants of water stress. Additionally, numerous studies have been conducted in different parts of the country on various crops to quantify the benefits of the use of drip irrigation in terms increase production and productivity as well as saving of water (Padmakumari and Sivanappan, 1989; Raman, 1999; Sivanappan, 1999). Furthermore, irrigation system is defined as the system that enables water to be acquired, transported and supplied to the farming field. It consists of two mechanisms:

- hydraulic infrastructure and
- the organization in charge of managing the water through the network.

However, the efficiency of these systems is often compromised by sediment transport, a dynamic process where soil particles are carried by water flow. Sediment affects water conveyance, infiltration, and system operation, making it a critical factor in irrigation management. However, according to Berg and Carter (1980) and Trout (1996) poor design as well as management, non–uniformity of water application, plus over– irrigation featured in surface irrigation are responsible for inefficient irrigation, leading to wastage of water, water logging, salinization, and pollution of surface and ground water resources. Furthermore, they noted that, irrigated agriculture is under serious risk due to substantial soil losses from extremely erodible soils. Enhancing water management of irrigation schemes through sediment management is required in order to achieve adequate water supply and food production (Kisi, 2012; Kuscu *et al*., 2009). It was from the above premises that the research on the effect of sediment transport on irrigation efficiency was initiated to disseminate reliable information of the subject matter.

SEDIMENT TRANSPORT IN IRRIGATION SYSTEMS

The essential properties of a sediment particle, especially with respect to possible transport, are size, shape, plus composition (Sherman and Davis, 2013). They continued to posit that a population of mixed – size particles, characteristically found in nature, is usually described in terms of the statistical. Sediment flow from agricultural fields can cause downstream water quality degradation and eutrophication by carrying soil and plant nutrients and other pollutants. The sediment transport in an irrigation season varies with the number of previous irrigations, flow rate, soil type, field slope, and field length (Mateos and Giraldez, 2005 and Mailapalli *et al*. 2009). However, sedimentation has been reported as one of the key problems affecting irrigation schemes within the African region and Eastern South Africa, where Mozambique is located. Different studies carried out in recent time in respect to irrigation schemes such as Southwest Kano Irrigation Scheme in Kenya (Ochiere *et al*, 2015), Metahara Scheme in Ethiopia (Ali *et al*., 2014), Gezira Irrigation Scheme in Sudan (Osman, 2015), around Suburban Tropical Basin in Congo (Lootents and Lumbu, 1986), plus Irrigation Schemes in South Africa (George *et al*., 2010) pointed out that these irrigation schemes are experiencing such challenges.

Sediment in irrigation systems emanates from different sources:

- Soil erosion: from agricultural lands, forests, and construction sites due to rain and runoff
- Weathering of rocks: physical and chemical breakdown of rocks produces soil and loose particles
- Streambeds and Riverbanks: erosion during high flows contributes sediments
- Coastal erosion: wave action erodes cliffs and shorelines
- Wind erosion: especially in arid regions, where fine particles are blown away
- Mechanisms of sediment transport depend on the following agent (wind, ice, gravity):
- By water (Fluvial Transport): fine particles such as silt and clay are carried within the column, sand – sized particles bounce along the riverbed, in addition to larger particles roll or slide along the bottom
- By wind (Aeolian Transport): medium – sized particles lifted briefly and dropped, in addition to larger particles roll along the ground
- By Ice : sediments are embedded in or pushed by moving glaciers
- By Gravity: movement down–slope due to gravity, including landslides, rock–falls, as well as soil creep

IMPACTS ON IRRIGATION EFFICIENCY

Irrigation efficiency can be said to be the measure of irrigation performance in terms of the water required to irrigate a field, farm, basin, irrigation district, or an entire watershed (Howell, 2003). Furthermore, Heermann *et al*. (1990) noted that irrigation efficiency is a vital engineering terminology used in irrigation science to characterize irrigation performance, evaluate irrigation water use, as well as to enhance better use of water resources, particularly those used in agriculture plus landscape management. Consequently, this impact on irrigation, reduced conveyance efficiency through silted pipes and canals, which decreases the flow rate, resulting in delayed water delivery and higher seepage losses. Sediment – laden water can create uneven distribution in surface and sprinkler systems, leading to over – irrigation or water stress in parts of a field. In addition, fine sediments may settle on field surfaces, reducing infiltration rates and increasing runoff. Similarly, high sediment loads can carry nutrients, pesticides, and pathogens, affecting plant health and soil quality.

EFFECTS ON IRRIGATION INFRASTRUCTURE

Sediment transport is one of the most basic and important processes responsible for shaping the earth's surface and is thus of fundamental interest to geomorphologists (Sherman *et al*., 2013). Sediment transport as well as the water flow are interrelated and cannot be separated (Mendez, 1998). Sediment transport affects infrastructure in several ways and this include canal siltation, clogging of gates and outlets (sediments can block control structures, affecting flow regulation and water allocation and wear and tear which involves abrasive sediments erode canal linings, pumps, and sprinkler nozzles, leading to frequent maintenance and replacement. Additionally, Ali and Hassan (2014) noted that irrigation systems, whether it is surface, sprinkler or drip irrigation, it can be affected by sediment carried in the irrigation water. Furthermore, sediments can accumulate in pipes, nozzles, or channels, reducing water flow as well as efficiency. They can as well clog filters, leading to maintenance issues.

MITIGATION STRATEGIES

Sediment deposits have to be removed to maintain irrigation supplies, and hence this is an acceptable part of maintenance in schemes with a small sediment input, desilting costs become excessive when large quantities of sediment settle in canals (Chancellor *et al.* 1996, Chancellor, 1991). Furthermore, the options for reducing sediment loads entering and settling in irrigation systems include: improved catchment management to reduce the sediment loads supplied to rivers, sediment detention structures such as check dam or small reservoirs constructed in a catchment to trap sediment before it enters a main river system. In addition, they noted that sediment exclusion structures located at the entrance to canal networks, or extraction structures located within canal networks (Chancellor *et al.,* 1996; Lawrence, 1996). In the same way, Carter (1976) reported that, when water flows over cultivated land, erosion may occur. When surface runoff from eroding fields enters a surface river or stream it contains sediment. Therefore, to control erosion in irrigated fields would also control the sediment in return flows expertise for mitigating erosion on irrigated land is accessible, but complete control is difficult. The most acceptable method for mitigating sediments from entering return flows and for removing sediment from return flows before they enter natural rivers and streams include; eliminate irrigation return flows, control the irrigation furrow slope, control the furrow stream size and make proper stream adjustment, shorten the length of run, manage the irrigation duration to reduce the number of irrigations per season in addition, to cultivating only when necessary and utilize sediment retention basins to remove sediments from surface return flows. Lastly, proper irrigation water management and irrigation system design are the first requisites for mitigating sediments in irrigation return flows.

INTEGRATED MANAGEMENT APPROACHES

There are different approaches to addressing sediment impacts and such include but not limited to watershed management, which involves soil conservation, afforestation and contour farming reduce sediment yield at the source (Tigkas *et al.,* 2012). Similarly, monitoring and modeling, which involves sediment transport models help predict problem areas and plan interventions, as well as effective institutional frameworks are needed to support sediment control and irrigation maintenance (Tigkas *et al.,* 2012). Furthermore, (Chancellor *et al.,* 1996 and Lawrence and Atkinson1989) posited that as soon as satisfactory estimates have been observed then technical expertise is needed to make selection one or more sediment control options to be compared with the without project scenario. Again, it becomes necessary to make quantitative predictions of the performance of a range of sediment control options to enhance the provision of estimates of annual sediment balances in the inland waterway system.

CONCLUSION

Sediment transport plays a critical role in determining the efficiency, reliability, and sustainability of irrigation systems. As reviewed, sediments originating from natural and anthropogenic sources can significantly impact water conveyance, distribution uniformity, infrastructure durability, and overall agricultural productivity. The deposition of sediments in irrigation channels and components reduces flow efficiency, increases maintenance costs, and disrupts field–level water application. Addressing these challenges requires a comprehensive approach that includes proper irrigation system design, erosion control practices, regular maintenance, and the implementation of sediment control structures. Furthermore, integrated watershed management and predictive modeling offer long–term solutions to minimize sediment loads at the source. Finally, enhancing irrigation efficiency amid sediment transport challenges is vital for ensuring water resource sustainability, and improving food security in sediment–disturbed regions.

References

[1] Ali, M., Hassan, M. A. (2014). Impact of sediment transport on irrigation system performance. Irrigation and Drainage Systems Engineering, 3(1), 1–7.

[2] Ali, Y.S.A., Crosato, A., Mohamed, Y.A., Abdalla, S.H., Wright, N.G. (2014) Sediment balances in the Blue Nile River Basin. Int. J. Sedim. Res., 29, 316–328.

[3] Berg, R.D., Carter, D.L (1980). "Furrow erosion and sediment losses on irrigated cropland," Journal of Soil & Water Conservation, vol. 35, no. 6, pp. 267–270, 1980.

[4] Carter, D. L (1976). Guidelines for sediment control in irrigation return flow. Journal of environmental Quality, Vol. 5, No. 2

[5] Chancellor, F., Lawrence, P., Atkinson, E. (1996). A Method for Evaluating the Economic Benefit of Sediment Control in Irrigation Systems. Report OD/TN 81

[6] Chancellor, F. (1991). A method for evaluating the economic benefit of sediment control. OD/TN 59, HR Wallingford, Wallingford, Oxon, UK.

[7] George, M.O., Olumuyiwa, I.O., Fred, O.A.O. (2010). Irrigation Canal Simulation Models and Its Application to Large Scale Irrigation Schemes in South Africa. A review. 2010. Available online: https://www.researchgate.net/publication/228322052

[8] Heerman, D.F., Wallender, W.W., Bos ,M.G. (1990). Irrigation efficiency and Uniformity. In Hoffman G.S., Howell, T.A., Soloman, K.H.,(Eds), management of farm Irrigation system ASAE, St Joseph, M.I., pp. 125–149.

[9] Howell, T. A (2003) Encyclopedia of Water Science DOI: 10.1081/E–EWS 120010252 by Marcel Dekker, Inc.

[10] Kisi, O.(2012). Modeling discharge–suspended sediment relationship using least square support vector machine. J. Hydrol., 456, 110–120.

[11] Kuscu, H.; Bölüktepe, F.E.; Demir, A.O.(2009). Performance assessment for irrigation water management: A case study in the Karacabey irrigation scheme in Turkey. African Journal of Agric. Res., 4, 124–132.

[12] Lawrence, P (1996). Soil Erosion and Sediment Yield, A review of sediment data from rivers and reservoirs. Report prepared for FAO Rome, HR Wallingford January 1996.

[13] Lawrence, P and Atkinson E (1989). Sediment control in the Agno River Irrigation System, HR Wallingford (unpublished Internal Note).

[14] Lootens, M.; Lumbu, S.(1986). Suspended sediment production in a suburban tropical basin (Lubumbashi, Zaire). Hydrol. Sci. J. Sci. Hydrol., 31, 3.

[15] Mateos, L., Gir´aldez, J.V. (2005). "Suspended load and bed load in irrigation furrows," Catena, vol. 64, no. 2–3, pp. 232–246, 2005.

[16] Mailapalli, D.R., Raghuwanshi, N.S., Singh, R. (2009). "Sediment transport in furrow irrigation," Irrigation Science. vol. 27, no. 6, pp. 449–456, 2009.

[17] Méndez_V, N.J.(1998). Sediment Transport in Irrigation Canals; Wageningen Agricultural University, Balkema: Rotterdam, The Netherland.

[18] Obineche C.I (2018). Effect of deficit irrigation on growth, Yield and Water Use of Okra. Master's Thesis, Agricultural and Bioresources Engineering Department, Michael Okpara University Of Agricvulture Umudike, Abia State Nigeria.

[19] Obineche I. C., Ahaneku I. E., Emeka–chris C. C (2021). Effect of Deficit Irrigation on Growth, Yield and Water Use of Okra in Owerri, Imo State, Nigeria. Umudike Journal Of Engineering and Technology (UJET); vol. 7, no. 1, pp. 32–39

[20] Ochiere, H.O.; Onyando, J.O.; Kamau, D.N. (2015). Simulation of Sediment Transport in the Canal Using the HEC–RAS (Hydrologic Engineering Centre—River Analysis System) In an Underground Canal in Southwest Kano Irrigation Scheme—Kenya. Int. J. Eng. Sci. Invent., 4, 15–31.

[21] Onwualu , A.P.,C.O.Akubuo,and I.E.Ahaneku. (2006). Fundamentals of Engineering for Agriculture.Immaculate publications Ltd. Enugu.

[22] Osman, I.S.E.(2015). Impact of Improved Operation and Maintenance on Cohesive Sediment Transport in Gezira Scheme, Sudan; Wageningen University; UNESCO–IHE Institute for Water Education: Delft, The Netherlands.

[23] Padmakumari,O. and Sivanappa, R.K. (1989). Drip Irrigation for Papaya. Proceedings of the 11th International Congress on Agricultural Engineering, Sept. 4 – 8, Dublin, Irland, pp: 134 – 136.

[24] Raman, S. (1999). Status of research on micro– irrigation for improving water use Efficiency in some horticultural crops. Proceedings of the National Seminar on Problems and Prospects of Micro– Irrigation– A Critical Appraisal, 19 –20, Institution of engineers, Banglore, pp;31 – 45.

[25] Sherman D.J., Davis L., Namikas S.L. (2013) Sediments and Sediment Transport. In: John F. Shroder (ed.) Treatise on Geomorphology, Volume 1, pp. 233–256. San Diego: Academic Press.

[26] Sivanappan, R.K. (1999). Status and perspectives of micro – irrigation research in India. Proceedings of the National Seminar on Micro – Irrigation Research in India: Status and Perspectives for the 21st Century, July 27–28, Institution of Engineers, Bhubaneswar, pp: 17–29.

[27] Tigkas, D., Tsanis, I. K., Baltas, E. (2012). Assessment of sediment yield in a Mediterranean watershed using SWAT. Water Resources Management, 26(6), 1639–1653.

[28] Trout, T.J. (1996). "Furrow irrigation erosion and sedimentation: on–field distribution," Transactions of the American Society of Agricultural Engineers, vol. 39, no. 5, pp. 1717–1723.

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