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''Mediated'' Negotiation Over the Grand Ethiopian Renaissance Dam: Achievement, Challenges and Prospect

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Abstract

The Nile river is the origin of African civilization. Egypt was considered for many years as hegemon for the Abbay/Nile River utilization by the international community. Hence, Egypt act as if it is until Ethiopia starts building a dam that will be the largest hydroelectric project in the continent, the Grand Ethiopian Renaissance Dam(GERD). But, the construction of the dam was not smooth. It was full of controversy and war-probing acts which led to the need for negotiation and then to the intervention of third party as 'mediator'. Thus, this study explored the main achievements gained after the tripartite negotiation started being 'mediated', challenges faced for not reaching on agreements still, and the future prospects on the negotiation ahead. The study employed exploratory research design and used content analysis as a method of analysis by using neo-liberal institutionalism as a theoretical approach perspective to analyze the situation on backing up by regime theory analysis. The main findings of the study showed that even if many scholars gave Egypt the status of hydro-hegemon on Nile river, most experts and authorities related to the issue that Egypt was not hegemon at all rather the upper riparians lacked the ability to develop hydro-projects until few years back. The main challenges, according to the study, for not reaching an agreement till now even with third party 'mediation' is due to lack of political will, impartial act of 'mediation' and using the negotiation as a tool of winning a leverage for domestic political gain. Finally, it is concluded that the so called 'mediation' is not mediation but a facilitation and has bring nothing apart from the progress attained with the tripartite negotiation. Therefore, it is recommended that the disputant states to show political willingness, to consider compensation and to show decency in respecting international law.

Keywords: Ethiopia; Abbay/Nile River; Egypt; hydro-politics; hydro-hegemony; cooperation

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1.INTRODUCTION

International river basins cover more than half of the land's surface (UN Water, 2014). With nearly 300 major watercourses shared by two or more states and ever-increasing pressure on the world's dwindling water supplies, some commentators might be justified in predicting "water wars" in the foreseeable future (Vinogradov, et al., 2003).

Riparian states' interests in the use and creation of globally shared basins naturally differ. While one state may be interested in harnessing a river's hydropower capacity, another may be concerned about the effects of a dam on the river's flow or sediment load on its own agricultural growth potential. As a result, riparian states often have disputes and conflicts, particularly when states view their neighboring states use of river resources as a threat to their own water security (Schmeier & Vogel, 2018). Recent conflicts over hydropower projects on the Syr Darya and Mekong rivers in Central and Southeast Asia, as well as the world's longest river, the Nile, are examples of this (Schmutz & Sendzimir, 2018).

There have been 37 instances of acute water dispute, since 1948 despite the fact that 295 international water agreements have been concluded and signed over the same time span. And, these days there are international agreements in effect for 20 of Africa's 63 river basins, and in 16 river basins there are institutionalized forums that have the task of coordinating national initiatives. Despite this, limited number of formal coordination forums, trans-boundary water management has made considerable progress (Scheumann & Neubert, 2006).

The Nile River basin is one of the trans-boundary river basins that crosses the borders of many countries (Wondwosen, 2009). The Nile River is the longest river in the world, and the total area of the river basin is more than 3,349,000 Km2. Also, the basin is, within its boundaries, a home to around 160 million people along within its ten riparian countries, the Nile shares water for about 300 million people (UNESCO, 2006). The Nile River has supplied, and as claimed ‘‘nearly all of Egypt's fresh water’’ for agriculture, industry, and human consumption since ancient times. The Democratic Republic of the Congo (DRC), Rwanda, Burundi, Tanzania, Kenya, Uganda, Ethiopia, Eritrea, and Sudan provide all of the Nile River's water. However, Egypt's overwhelming economic and military power, in comparison to the upstream countries' lack of capital, limited capacity to build dams and waterworks, and internal strife allows it to wield enormous control over how the Nile's water resources are used. (Klare, 2001).

Egypt, Sudan, and Ethiopia makeup the Eastern Nile Basin. In fact, about 85 percent of the overall Nile River flow originates on Ethiopian territory (Swain, 2011). As a result, the Blue Nile River is Ethiopia's largest and the world's longest trans-boundary river with significant hydropower and irrigation potential. So, Ethiopia contends that developing this resource is critical to its economic and social development, and the country's ability to overcome poverty and famine which have plagued it in the past. In addition, Ethiopia has the best hydropower potential country in the basin, and damming the Blue Nile would significantly rise Sudan's irrigated agriculture potential. In current reality, Ethiopia has never 'consumed' significant amounts of Nile water in the past, because of its previous political and economic fragility, combined with a lack of external financial support as a result of persistent Egyptian opposition to projects upstream, prevented it from implementing large-scale projects. (Wondwosen & Lind, 2013).

Ethiopian willpower to construct a major dam for hydropower purposes, the Grand Ethiopian Renaissance Dam (GERD), has become a turning point in current conflict-of-interest within the riparian countries. (Goitom, 2014). While Ethiopia's and other upstream countries' current water development plans only call for a small portion of the Nile's water, hence, downstream countries Egypt and Sudan are concerned about the prospect of increased water use in the near future. (Pearce, 2015). According to a 1959 agreement, Egypt and Sudan have shared a common position with other riparian regarding the use and management of Nile waters for several decades. (Climate Diplomacy, n.d.). This bilateral treaty between Egypt and Sudan in 1959 demonstrates both countries' willingness to work together to counter claims for water allocation by other riparian states. (Reuters, 2010). As a result, the Nile water agreement signed by Sudan and Egypt in 1959 did not put an end to the dispute over Nile water rights, and tensions remain high. Ethiopia's plan to build the GERD in 2011 poses a significant political challenge towards the 1959 Agreement. It marks the end of Egypt's de facto ‘‘veto power’’ over major upstream dams, and it clearly demonstrates Ethiopia's political will to develop its water infrastructure even in the absence of a comprehensive basin agreement. (Goitom, 2014).

The GERD's construction fundamentally altered the power balance on the Nile River. The old water contracts no longer provide Egypt with any protection against restrictions on its own water supply. And, recurring threats from Cairo to use military force to halt the dam construction project are unlikely, not least because of the distance between the two countries. Efforts to exert pressure on Ethiopia through the mobilization of allied states have also been futile so far. (Lossow, et al., 2020).

Following the announcement of the dam's construction and in response to rising tensions, the Ethiopian government invited Egypt and Sudan to form an International Panel of Experts (IPoE) to gain a better understanding of the GERD benefits, costs, and impacts. A tripartite National Committee (TNC) comprised of national experts from these three countries was formed between August and October of 2014. While, signing the Comprehensive Framework Agreement (CFA) in March 2015, Al-Sisi and former Ethiopian Prime Minister Hailemariam Desalegn acknowledge the agreement as ‘‘a new chapter in relations between Egypt and Ethiopia based on openness and mutual understanding and cooperation'' (Climate Diplomacy, n.d.). However, a deal is still a long way off. After these developments the TNC has been unable to reach an agreement on technical reports on the dam's potential impacts yet since 2015 (Maguid, 2017).

Following talks between the three countries' water resources Ministers in Khartoum, Sudan's capital, Egypt announced that talks on the GERD had come to a halt and called for international mediation. Cairo did not specify who should mediate, but the presidency urged the U.S to play "a proactive role" in the matter. (Abdelaziz & Mourad, 2019). However, Ethiopia claimed that through its water Ministry, the U.S mediation efforts over its Nile River dam project had disappointed it, implying that a deal would not be reached soon (Africanews, 2020). And, the trilateral talks broke down after Ethiopia ‘‘rejected a binding agreement’’ with Egypt and Sudan on the filling and operation of the GERD which was mediated by the U.S and the World Bank (Kandeel, 2020). Thus, Heads-of-States from Egypt, Sudan, and Ethiopia attended an African Union (AU) mini-summit to discuss on the GERD. Egypt's President Abdel Fattah Al-Sisi, Sudan's Abdalla Hamdok, and Ethiopian Abiy Ahmed agreed to a process led by the A.U to resolve outstanding issues (Samir, 2020).

Questions about how the reservoir of the GERD will be filled and for how long are gaining traction. In light of this, the US launched a new mediation effort at the end of 2019 (Lossow & Roll, 2020). However, in September, the Trump administration announced that Ethiopia's aid budget would be cut by $130 million, intervening in favor of Egypt and this heightening tensions. While, the problem is complicated and needs careful mediation, the Trump administration has taken a different path by cutting aid to Ethiopia. In practice, the sudden change has exacerbated the conflict, hardening Ethiopia's resolve, strengthening Egypt's nationalism, and weakening the U.S legitimacy as an international and impartial mediator. Fortunately, the path forward didn’t rely on the United States. Negotiations started to be led by the African Union, a more honest and informed broker (Paduano, 2020). The first meeting took place in late June, and a follow-up video teleconference chaired by South African President Ramaphosa was held on 21 July 2020 with the view of reviewing progress made with the trilateral negotiations. But, as Owojori (2020) any negotiations among the countries is yet facing a number of tricky points of contention (OWOJORI, 2020).

Despite the threat of withdrawal, suspension or walkout by Egypt and Sudan, they were urged by the then South African President to continue talks (AFP, 2020). Some global medias even mentioned that talks over the operation of the GERD are deadlocked (Reuters, 2021).

Recently, it is reported that the latest A.U-led talks have been suspended after Sudan, whose officials are courting with Cairo, refusal to attend (Ethiopian Monitor, 2021). And, authorities and experts are saying that there is no substantive progress seen within the past four years on the negotiation over GERD (Eyssen, 2020).

The main issue of contention explained by different media outlets as water release during dry years to come (Sterl, 2021); dam safety and regular water flow (The Arab Weekly, 2021); and filling period of the GERD and its effect on downstream countries’ dams, especially Egypt’s (Addisu, 2020). Despite all the areas of disagreement among these countries, there is no clear and detailed explanation on the things that they agreed on, the remaining work-ups, and the exact progress on the negotiation. Authorities of the countries are seen with words exchanges and accusing each other without specifying what particular challenges have to be solved.

Thus, this study will try to examine and analyze the aforementioned issues so that it will fill the gap by contributing to current literature of hydro-politics and hydro-hegemony, if any, and cooperation by providing both firsthand opinions of experts, concerned authorities and stakeholders, and comprehensive information from wide exploration of literatures on negotiation with the help of international mediation over the Nile River Basin water utilization, the GERD operation, and challenges to their cooperative efforts including the prospects. Therefore, this study tried to explore and analyze the challenges and prospects of international mediation on the negotiations over GERD.

2.MATERIALS AND METHODS

2.1.Description of the Study Area

For the research tried to analyze challenges and prospects of mediated negotiation between the three riparian countries, the study included notions, stances by different countries towards the GERD negotiation but the study area is bounded to Ethiopia for the remaining countries could not be reached with every means due to the distance from home country and unwillingness of their embassies to respond to the study questions.

3.RESEARCH METHODOLOGY

The thesis has mainly used inductive qualitative methods in order to provide a detailed and thorough analysis of the raised research questions. Qualitative research will be able to elicit more detailed information about a phenomenon. They are the most appropriate ones for the purpose of this study. The researcher used exploratory research design for the researcher does not aim to provide final and conclusive answers to research questions rather aims to explore specific aspects or perspectives of the research area. Inductive research approach was also used where data was collected from the experience, and knowledge of key informants to explore a phenomenon, identify themes and patterns and create a conceptual framework which is used to generalize and draw a conclusion.

For this study the key informants were selected purposively on the basis of their specialist knowledge and position that enable them to have detailed and expert level knowledge of the current issue regarding the GERD and mediation on the negotiation with Nile Basin countries.

3.1.Methods of Data Analysis

The researcher employed qualitative data analysis. Qualitative data refers to non-numeric information such as interview transcripts, notes, video and audio recordings, images and text documents.

Specifically, the researcher tried to analyze the data by using content analysis. This method is used to analyze content from various sources, such as interviews of respondents, observations from the field, online contents or surveys.

3.2.Results and Discussion

‘Mediated’ Negotiation Over GERD: Achievements, Challenges and Prospect

4.NEGOTIATION OVER GERD: THE PROCESS

In the Nile Basin, Egypt has long been the dominant hegemon. Egypt has established effective hydro-hegemony in the Nile Basin through a variety of mechanisms, including a series of colonial treaties. This has made it impossible for upstream countries, like Ethiopia to use the Nile's waters (Tekuya, 2018). Furthermore, Egypt has used its Middle East strategic position to block international funds intended to assist Ethiopia in developing the Nile. (Thurow, 2003) (Swain, 2002). Accordingly, Ethiopia had been unable to develop irrigation projects for a long time due to a lack of funds. This resulted in "one of Africa's cruelest ironies: the land that feeds the Nile is unable to feed itself (ibid)." Thus, Ethiopia eventually decided to change the game by building the GERD.

Security in Northeast Africa has once again been threatened by disagreements over the filling and operation of the GERD. Ethiopia claims that the dam will have no significant negative consequences for Egypt and Sudan, the two countries downstream. Indeed, Ethiopia claims that the GERD provides enormous benefits to Egypt and Sudan, including a more consistent water supply, better siltation prevention, reduced evaporation, and lower electricity costs (Tawfik, 2016). And, each Nile state's demand for water has increased as a result of population growth and improved living standards, and the river has, thus, become an important part of interstate politics(Wolf, 1998).

Egypt, argue that any upstream dam on the Nile River poses an existential threat (Salman, 2016). As a result of this Cairo's political stand initially it turned down the project outright. However, Egypt later requested that Ethiopia conduct an independent trans-boundary impact study before proceeding with the GERD construction (Tawfik, 2016, p. 22). Then, when Ethiopia refused to halt the GERD construction, Egypt demanded that the dam be reduced in size (Zeray, 2020). As a result of these differences, among Egypt, Sudan, and Ethiopia then signed the DoP on the GERD in 2015 after years of arduous negotiations. Egypt's recognition of the Nile River's importance to Ethiopian development is reflected in the DoP, which provides a framework for further negotiations on the dam's filling and annual operation.

Despite this framework, there is still a disagreement about how the GERD should be filled and operated. Egypt is adamant about preserving its historic water share (Dahan, 2009), and as a result, it has demanded that the GERD reservoirs be filled over a long period of time, roughly twenty years (Elias, 2020), and that it be given a say in the dam's operational management.

Moreover, Ethiopia does not recognize the Egyptian claim of "historic rights" regarding the Nile, and despite the Blue Nile's ability to support a three-year fill period, Ethiopia has offered to fill the reservoir over a period of four to seven years (Lewis, 2019). Also, Ethiopia demands exclusive management of the dam and its operations because the GERD is a national project located entirely within Ethiopian territory. Sudan, on the other hand, supports the GERD despite some safety concerns (Salman, 2017).

The three states have been unable to resolve these issues for more than five years. Consequently, Egypt submitted proposals on the dam's filling and operation in August 2019, and the GERD negotiations were effectively internationalized after the U.S government and the World Bank were invited to participate as observers. Ethiopia rejected the proposal and canceled its participation in the last meeting in Washington, D.C. (Tekuya, 2021).

The U.S Department of the Treasury has also asked Ethiopia to sign the 'Washington talks' proposed agreement and has warned it not to test or fill the GERD until Egypt and Sudan have reached an agreement (Mnuchin, 2020). Ethiopia expressed its dissatisfaction with the statement and announced that, as agreed the three riparian States in the DoP, it would fill the reservoir concurrently with the dam construction (Embassy of Ethiopia-London, 2020). Egypt, on the other hand, signed the U.S and 'Washington talks' proposal and pledged to defend its Nile River interests "by any means necessary" (Haaretz, 2020). Asfaw rejects the deed of the US raising the role of the US was limited to only observer.

The current tension between Ethiopia and Egypt is primarily related to their longstanding disagreement over the validity of the 1902 Anglo-Ethiopian Treaty, the 1929 Anglo-Egyptian Treaty, and the 1959 Nile Treaty between Egypt and Sudan, collectively, the "colonial Nile Waters Treaties", which has been hidden behind talks over the GERD's filling and operation (Tekuya, 2021, p. 72). In view of this reasons, the GERD negotiations are being hampered by this disagreement, which peaked during the negotiation of the CFA. Egypt, on the other hand, continues to argue that any upstream dam on the Nile River poses an existential threat (Salman, 2017, p. 516).

4.1. Achievements of the GERD Tripartite Negotiations and Its ''Mediations''

There are so much open-ended arguments on the GERD's either on the tripartite negotiation, or its ''mediation'' that includes the U.S and the A.U. On the past, negotiations on the issue of the Nile waters always were stuck on the narratives of Cairo's unwillingness based on its logic of the Nile River water ''historical rights.'' But since 2011, Ethiopia and the two downstream countries, which are Egypt and Sudan got engaged on the GERD negotiation tables. The mainstream public discourse narratives towards the GERD become reverse as Gadissa Belayneh stipulates;

Egypt wants to hook up one big fish from the discussions on the GERD. And that big fish is Ethiopia and the issue is the 1959 "Agreement". Egypt calls it a "historic right" but it is a "historic wrong" for Egypt itself. Egypt wants this "historic wrong" be recognized by Ethiopia. IN other words, Egypt is asking 'Ethiopia to throw away its sovereign and natural right of utilizing the Nile and carry an Egyptian colonial yoke and deprive its people of their basic right of quenching their thirst from their Nile waters (Gadissa, 2017).

Moreover, as the Crisis Group the issue of the Nile water also become the Nile Basin's other riparian countries interest either in short or long terms that;

Authorities in Addis Ababa, Cairo and Khartoum should lay the ground for more substantive discussions of a long-term framework for Nile basin management to avert similar crises in the future. Egypt should re-join the Nile Basin Initiative, the only forum that brings together all riparian countries and the best venue available for discussing mutually beneficial resource sharing. A permanent institutional framework could also help the countries prepare for challenges down the road, including climate change-induced environmental shocks, notably variable rainfall patterns, which could cause greater water stress (Crisis Group, 2019, p 4).

And for Addis Ababa this, by contrast, offers a grand momentum towards a rational utilization of the Nile waters. By far, and implicitly, this made Ethiopians to hold new status on the Nile River waters that is regionally and on system level Cairo's ''natural rights'' narratives replaced by a ''fair and equitable'' water utilization Addis Ababa's counter-arguments. Hence, this brings opportunity not only for Ethiopia, but it does ensure its own merits for the rest Upper stream countries.

Further, Ethiopian negotiation capability also become tangible on the system's negotiation and mediation table. U.S and Europeans' diplomatic pressure through ''suspending aid and loan" to the Ethiopian government; and as well, the latest U.S ''travel visa ban'' on Ethiopian State officials became into light how the Addis Ababa government 'mediations' procedure and its flexible influence make the 'international mediation' to became opportunity-gainer from the 'international mediation.' Subsequently, the President Biden administration's tight diplomatic pressure on Addis Ababa firms Ethiopia's stand towards GERD, in parallel with by way of manifesting Ethiopian sphere of influence via cooperating with international institution logic of neoliberalism institutionalism thought, on the U.S involved negotiations' or mediation's table, Ethiopia gain its negotiation leverage and capability's upper-hand as an opportunity on the base of extra-actor pressure towards the country.

4.2 'Mediated' Negotiation over GERD: The Challenges

The three countries have been engaged in a series of negotiations in an attempt to resolve the conflict for several years. In October 2019, the three countries agreed or were compelled to enlist the assistance of the United States and the World Bank in order to break the impasse (Zeray, 2020). Even if it is true that third-party mediation by the United States and the World Bank (WB) is not Ethiopia's preferred option, Egypt is seen as more important to the United States from a geopolitical standpoint than Ethiopia (Yohannes, 2020). Seleshi Bekele, Ethiopia's Minister of Water, Energy, and Irrigation, expressed this sentiment when he said, "Why do we need new partners? Do you wish to continue the negotiations indefinitely?" As a result, the Egyptian request for a mediator was turned down (Abdelaziz & Mourad, 2019).

As a result, as discussed further below, the first challenge for a successful 'mediated' negotiation is a distorted first impression of the United States as a 'mediator' of the GERD negotiation. However, the United States, along with the World Bank, intervened as an observer, offering to break the deadlock in years of negotiations. In spite of the US Treasury and the President of the WB participating as observers in negotiations', and the three countries agreeing to instruct their legal and technical teams to prepare an agreement, the USA, stepped in to draft an agreement for which the parties were invited to a meeting to sign (Zeray, 2020).

This irritated Ethiopia, which expressed its displeasure in a statement issued by the Council of Ministers on 1 March 2020, in which it stated that any agreement that jeopardizes Ethiopia's sovereign rights and interests would be rejected (ibid). While Ethiopia's position clarified and emphasized the country's difficulty accepting the United States' point of view, (BBC, 2020). Asfaw explained this situation to the researcher during an interview, "Ethiopia couldn't accept the agreement prepared by the US for it didn't invite or accept the mediator role of US." (Asfaw, 2021) Egypt, for its part, accused Ethiopia of obstructing the process on purpose in violation of the 2015 DoP (Al-Youm, 2020).

Ethiopia accepted the involvement of US and WB to show the commitment of the state to reach on a win-win agreement for both states, unlike the blame by Egypt. In addition, Ethiopia can raise a question of violating of the DoP by Egypt and Sudan, where it is on the document that states should reach an agreement without the intervention of third party prior to exhaustively use all means by technical experts and failed meeting at head of state level.

The Trump administration favored Egyptian President Abdel Fattah al-Sisi, a Trump ally, in its few forays into the GERD dispute. After Ethiopia rejected a draft agreement drafted by US, which it saw as heavily favoring Egypt, the Trump administration partially suspended American assistance to Ethiopia in July. If talks fail, President Donald Trump has publicly warned that Cairo will "blow up that dam" (Luck, 2021). Ethiopia expressed dissatisfaction with the United States' efforts to mediate over its Nile River dam project, implying that a deal will not be reached anytime soon (Africanews, 2021).

In such cases, the United States has attempted to act as a mediator. The situation is complicated and necessitates careful mediation, but the Trump administration has taken a different approach. Washington appears to be pressuring Ethiopia, by cutting aid to Ethiopia, to accept Egypt's demands, which include slowing the dam's filling and agreeing to deferred water-sharing quotas. In practice, the sudden move has exacerbated the conflict, hardening Ethiopia's resolve, strengthening Egypt's nationalism, and undermining the US' credibility as an international mediator. Officials from Africa have said that the US has unnecessarily become a source of instability in an already volatile situation (Paduano, 2020).

Egypt chose to internationalize the conflict, whereas Ethiopia prefers African Union (AU) 'mediation', through which it has been able to enlist the help of South African President Cyril Ramaphosa to mediate (Yohannes, 2020). Asfaw said that not only the U.S, but also AU is a facilitator for the negotiation, even if many are saying the negotiation is mediated by specifying "No state or institution participated in the past and now as a mediator but as a facilitator" (Asfaw, 2021). This is also raised by an expert in the same department of MoFA stating that "mediation is the act of facilitating an already started negotiation to reach an agreement soon, not further than that." (MoFA Diplomat, 2021). Belayneh Temesgen has a different view on this issue. Belay is a Civil Engineer, Hydrologist and Hydro-informatics expert who is also Boundary and Trans-Boundary Rivers Affair Directorate Director at Basins Development Authority in Ministry of Water, Irrigation and Energy. He stated that;

It will be difficult to get neutral mediator. The ideal mediator should have equal opportunity loss if it decides to favor one over the other and it must be morally of highest level. Our organization see the international mediation should wait and see how Ethiopia handles the filling and operations of its own Dam, GERD. Therefore, there is no need of mediation this time (Belayneh, 2021).

In addition, he named the 'mediation', where he didn't call it one, the act of the U.S as 'intervening with skewed position' for US was trying to impose binding agreement on Ethiopia for the sake of the interest of Egypt and US itself(ibid). Dereje, a lawyer and consultant for GERD also elaborated this situation by mentioning that a country will enter into negotiation and sign an agreement only if there is willingness and wouldn't sign an agreement if it harms national interest of the nation. Thus an agreement should not be imposed on any nation (Dereje, 2021).

The second challenges, besides the first attempt of the 'mediator' take an 'off-target shot', is the inability to negotiate on the most important and urgent issues for an agreement. The latest round of talks between Egypt, Ethiopia, and Sudan over a GERD dispute has come to a halt once again. Ethiopia, on the other hand, has declared its intention to fill the dam with or without an agreement after the relevant parties failed to convene a new round of negotiations.

The majority of their differences regarding the project's successful and peaceful operation have been resolved. Drought mitigation protocols and a dispute resolution mechanism, however, remain unresolved. The lack of resolution on these two issues is primarily due to the countries' differing perspectives on the entire issue of water governance in the Nile. Ethiopia points to the lack of a comprehensive legal agreement on water sharing in the Nile basin and rejects Cairo and Khartoum's calls for an internationally binding process on both issues. Instead, it prefers a trilateral mechanism involving only the three states, which Egypt and Sudan, though to a lesser extent, find unacceptable (Khorrami, 2020).

Asfaw appreciated the stance of Ethiopia in that it's following the track agreed by the DoP that the states should negotiate and agree on the filling schedule and operation of the dam with continuing construction of the dam. But, he said, to the contrary Egypt and Sudan insist on agreeing on deal related to future developments on the Nile and dispute resolution mechanisms which can be dealt in the future (Asfaw, 2021). The same but more elaborated response was also gotten from Belayneh said that;

Ethiopia has never recognized any intention of Nile river hydro-hegemony; although Egypt has tried to hold this position through many wicked political as well as policy strategies. Ethiopia has always even before the construction of HAD (High Aswan Dam) declared any miscalculation by anyone

(Egypt or Sudan) on the right (potential) of Ethiopia to develop any of the water of the tributaries of the Nile is a big mistake. The Status quo has been invalid and dead from the beginning or its birth. GERD is a manifestation of these all generation of Ethiopians and the rulers (Belayneh, 2021).

Where he expressed the notion of different scholars and even Egypt that Hydro hegemony was maintained by Egypt is a myth. But GERD might change the status quo, if any, on hydro hegemony when completed. The fear of this pre-conceived notion might also be a challenge for Egypt sticks on this notion of 'historical right'. Similar response was gained from Dereje, where he mentioned that the Egyptian's 'historical right' is invalid. According to Dereje, the 1929 treaty means nothing for Ethiopia due to the reason that Ethiopia was independent at that time and considered as third party for the treaty. The same treaty is invalid for the other riparians after their independence (Dereje, 2021), as seen in the Tanganyika declaration.

Furthermore, during the most recent round of technical talks, Ethiopia is said to have objected to Egyptian demands that the reservoir be filled over a period of 12 to 20 years, which is too far away for an Ethiopia that needs more immediate payback for its large investment and has argued for a filling period of only five to seven years (Johnson, 2020). Egypt and Sudan are seeking a legally binding agreement on the dam's filling in times of drought, which Ethiopia rejects (Yohannes, 2020). A diplomat from MoFA stated that Ethiopia is following all the agreed steps to continue the construction of the dam and fill the reservoir accordingly (MoFA Diplomat, 2021).

Blaming and deterring is also another challenge that leaves the states to go out of track for effective negotiation. Egypt has lobbied the United States, its Arab allies, and the United Nations Security Council to intervene. Foreign Minister Sameh Shoukry warned in June that if the United Nations did not intervene, there would be conflict. Following the breakdown of the talks, Egyptian state-controlled media called for the use of "force" against Ethiopia, advocating surgical strikes on the GERD's power grid (Luck, 2021).

Furthermore, Egypt has maintained its commitment to the concept of "historic right," despite Ethiopia's extraordinary efforts to accommodate Egypt's demands and ways. The only exception is Egypt's unjustified and completely unacceptable claim of 'historical right' and existing uses, which it is attempting to monopolize. This is demonstrated by the fact that Egypt and Sudan have a water-sharing agreement that denies Ethiopia its right to an equitable share of the water (Vidija, 2020). Asfaw elaborated on this issue stating that Egypt advocate a negative and wrong notion for its people telling them that Ethiopia is going to cut the waters of the Nile and let Egyptians vanish with thirst. He added, Egypt also tried to lobby the world that the dam has security issues and not safe for the downstream countries in terms of safety (Asfaw, 2021).

Asfaw expressed his belief that the three countries alone can negotiate for a better resolution of any dispute and he, personally hoped, and Ethiopia believed that "agreement will be reached soon if there is political commitment for cooperation." He further added that, "if negotiation can't solve the issue, mediation will not be the answer because choosing a mediator also needs an agreement. What the countries needed is thinking other country's benefit as if it is one's own and trying to agree with 'being in other person's shoe' concept" (Asfaw, 2021).

Dereje also mentioned that choosing an African institution for finding African solution for African problem alone would not bring solution rather if it's assisted with commitment to cooperate and work for collective development.

4.3 Prospects for the Negotiation Ahead

Most scholars including the experts interviewed are stipulating that the fate of the current negotiation or mediation is unpredictable. But even though there are hurdles and pitfalls on the process of the negotiation to reach to a final agreement, it is not as completely blocked to find a solution. The ideas gathered from the interviewees proved that there is still plenty of opportunities to harness for effective negotiation ahead.

The late flexibility of Egypt, as evidenced by the speech of El-Sisi that negotiation needs time and the GERD filling won't affect Egypt much, might be a breakthrough to discuss closely to find a better resolution soon. The belief that African solutions to African problems is becoming more internalized in the preferences and choices of the western countries including US, Russia, China and India; and international and regional organizations like UN and EU. This will create a sense of belongingness and proximity in culture, narration and objective that will facilitate the positive intention and action towards cooperative agreement.

The green legacy, an act of increasing the forest coverage of the country, being taken by Ethiopia for the last three consecutive years might be a good cause for having a large amount of rainfall during the rainy season which makes the fear of river flow reduction in the downstream countries void. This will ease one of the negotiation bottleneck.

Furthermore, it is known that the negotiation is yet to be over, rather is still in a deadlock. The claimed agreement prepared by the US included only the two downstream states and Ethiopia, excluding South Sudan. Coupled with the Ethiopian assumption that the 'agreement paper' was biased and didn't consider the right of Ethiopia and not including the newly formed state, South Sudan, the agreements that will be signed ahead shall consider South Sudan and other upper riparian countries.

The current fiasco between the negotiating countries will be dealt if and only if there is political will apart from having a reliable mediator, if needed. But the trend Sudan is following throughout the negotiation will determine the pace. The angling of Sudan and position it holds at a given time in the negotiation process will determine the position of both Ethiopia and Egypt to reach on an agreement as soon as possible, flexing their obstinate stance of their own. But as Dereje mentioned on the interview, negotiation should not be an obstacle for national development of a country specially where there is no commitment to reach to a win-win agreement based on a legal framework (Dereje, 2021).

5.CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Egypt has long been the dominant hegemon in the Nile Basin, or else it is believed so. Egypt has used its strategic position to defuse international funds that were supposed to help Ethiopia in developing projects over the Nile. Each Nile states, including Ethiopia's, demand for water has increased following exponential population growth and improved living standards. With rising water demand, there is a greater need to jointly utilize the Nile's water to meet the freshwater needs of all basin states. However, Egypt looks obstinate about preserving its historic water share and has demanded that the GERD's reservoir be filled over a long period of time. Ethiopia does not recognize Egypt's claim of "historic rights" regarding the Nile.

After Egypt asked US to intervene in the negotiation, department of the Treasury has asked Ethiopia to sign the proposed agreement and has warned it not to test or fill the GERD until Egypt and Sudan have reached an agreement. Egypt, on the other hand, signed the US proposal and pledged to defend its Nile River interests "by any means necessary".

The latest round of talks between Egypt, Ethiopia, and Sudan over a GERD dispute has come to a halt once again. Egypt chose to internationalize the conflict, whereas Ethiopia prefers African Union mediation. Officials from Africa have said that the US has unnecessarily become a source of instability in an already volatile situation. Ethiopia points to the lack of a comprehensive legal agreement on water sharing in the Nile basin and rejects Cairo and Khartoum's calls for internationally binding process.

The researcher found that the tripartite negotiation has contributed so many fruits for the upcoming negotiation and dispute resolution. But many scholars and also interviewees agreed that 'mediation' has bring none of what is expected that will facilitate final agreement and thus cooperation. If there is an achievement after mediation, it is only being handled by AU. It is considered as an achievement for the AU has no conflict of interest thus impartial and fair for all the negotiating parties. In addition, AU creates a sense of capability and notion that African problems have African solutions which is appreciated by many experts, analysts and states.

Yet, seeing no tangible results even after AU take the leading role in mediating the three states is attributed to a number of reasons. The first being the impartiality of the US as a first 'mediator' which creates sense of suspicion that was being blooming after signing of DoP. Another reason that can be mentioned is strategically and tactical shift of both Sudan and Egypt with every meeting for negotiation. In addition, the disagreement on choice of 'mediator' or as some scholars suggested, facilitators had contributed for failure for reaching an agreement. It is also found that even if many researches and scholars call the involvement of the US and the AU as mediators, there are also a number of experts including the ones that are interviewed call their involvement as facilitation but no more.

In addition, most of the literatures, articles and interviewed experts explained, negotiation has a great deal of importance for successful dispute resolution but mediation has no extra 'qualities' of helping these states to reach an agreement. Rather it is better to conduct the tripartite negotiation with transparency and positive will of cooperation. As Belayneh said "Egypt will realize Ethiopia's fair approach if it will. Cooperation is the only way out." Indeed, cooperation is the only way out. And as Dereje said, "In a competitive world where Africa is marginalized, It's hard to challenge the logic that standing together gives a strength and meaningful role in the world arena" (Dereje, 2021). But, he added, 'Mediators' like AU can only play a limited role, since they have structural limitations in negotiation by the influence, leverage and the power it has, but apart from that it can only play limited role where if a party that are not ready to resolve it is very unlikely to be resolved by a third party even when that third party is very strong with huge leverage on those parties. Therefore, cooperation and working together towards the attainment of prosperous nations in Africa should be the core concern of the states.

5.2 Recommendations

After carefully studying the historical and contemporary issues related to the GERD and the negotiation; and going through pertinent articles, journals and documents, it is clear that there has to be some change in the way the negotiation is being taken. It is known that Ethiopia has the sovereign right to utilize its natural resources including water, to improve the living conditions of its people. The Three Countries, Sudan, Ethiopia and Egypt shall cooperate on the basis of good faith, territorial integrity, sovereign equality and mutual benefit in order to attain rational utilization and appropriate protection of the River. The common objective of the Nile riparian should be to bring prosperity for their people.

Therefore, it is recommended that:

The states that are participating on the negotiation should detach the process from the act of expecting gaining political benefit and focus on finding a win-win solution for the benefit of all countries

The negotiating states have to show decency in respecting the principles of equitable and fairness in utilizing transboundary resources

The downstream countries should try to faithfully understand the reality, if the GERD really causes harm to their country for it is one of the main hurdle for the negotiation

Even if it is a must that Ethiopia should lengthen the period of reservoir filling, the downstream countries should consider compensation as a good faith based cooperation for the income Ethiopia loses in the process

Egypt is advised to correct the narration that led to the notion of giving the Abbay/Nile River for only Egypt and to amend its constitution, if needed, to create space for flexibility in dealing with such type of issues

The Europeans and US should work on other energy production and drought mitigating mechanisms for the negotiating states so that it won't be a reason that is served as an obstacle

The international financial institutions should fund, rather than taking a side and block developmental funds and loan, to upper riparian countries to utilize their alternative resources to reduce the burden of projects on the basin

International institutions and multinational companies should strengthen their institutional capacity and regulation to the extent that can deal with similar and even more complicated issues now and in the future

Finally, the international community should always support the idea of impartiality, fairness in utilization and cooperation so that it will be transparent who to help and which side to be inclined to

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Sunrays Treated Saline Water Application and Turnip Yield

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Abstract

Effective water quality management is crucial for sustainable agricultural development and optimal crop yield. The interplay of chemical, physical, and biological properties, along with water temperature influenced by solar radiation, holds a pivotal role in shaping water quality. Addressing the research gap in this area, this study focuses on the impact of solar radiation on changes in saline water quality parameters and turnip growth, while also comparing the effects with fresh water application. Conducted through controlled pot studies within a laboratory setting, the investigation utilized a Plexiglas tank/chamber to expose water to solar radiation. The quality parameters of the sunrays-treated water were subsequently analyzed, alongside the assessment of turnip growth. The findings reveal that, notably, there were no significant alterations observed in the physiochemical parameters of water, both in the case of low saline water and fresh water, following exposure to solar radiation. However, an impactful disparity in turnip yield emerged, with the application of fresh water yielding significantly better results. Moreover, water productivity demonstrated a notable increase when compared to low saline water treated with solar radiation.

This study not only sheds light on the intricate relationship between solar radiation and water quality but also underscores the influence of water quality on crop productivity. The implications of these findings extend to the potential optimization of water resource management for agricultural practices. As a stepping stone, further comprehensive studies are recommended to delve deeper into the multifaceted impact of solar radiation in irrigated agriculture, with the ultimate aim of formulating actionable and effective recommendations.

Chemical, physical, biological properties and water temperature plays big role on water quality. Water temperature depends mainly upon the amount of solar radiation in water. Technical research on using efficient, optimal water is crucial for sustainable agricultural development and vegetative and generative yield.

This paper highlights the impact of solar radiations on changes in saline water quality parameters and turnip growth in comparison with fresh water application during pot study in the laboratory. A Plexiglas tank/chamber was used for the application of sunrays on the water and sunrays treated water was analyzed for quality parameters and turnip growth. Results of the present study revealed that no significant changes in physiochemical parameters of water were observed both in low saline and fresh water. Turnip yield is significantly better with the application of fresh water and water productivity was found to be in higher than the low saline water treated with solar radiation. Further studies are suggested to evaluate in depth the impact of solar radiation in irrigated agriculture for making concrete recommendations.

Keywords: Water, saline water, solar radiation, turnip, productivity.

1. INTRODUCTION

Enhancing Turnip Yield through Innovative Sunrays-Treated Saline Water Application In recent periods, humanity has been grappling with two intertwined challenges: the gradual reduction of available freshwater resources and the urgent necessity to elevate agricultural productivity in order to nourish an expanding global populace. Consequently, researchers and agricultural experts have been delving into innovative methodologies to confront these issues while upholding the principles of sustainable food production. Among these pioneering methods, one has garnered substantial attention - the utilization of sunrays-treated saline water to amplify crop yields, with a specific emphasis on turnip cultivation.

Saline water, distinguished by its elevated salt content, has historically posed a noteworthy hindrance to agricultural productivity due to its detrimental consequences on both soil vitality and plant development. Nonetheless, harnessing the potency of solar radiation to treat saline water offers a propitious resolution. Through subjecting saline water to solar radiation, a range of processes including desalination, disinfection, and the decomposition of organic matter can transpire, rendering the water more suitable for purposes of irrigation. This innovative approach not only alleviates the adverse impacts of saline water on soil composition and nutrient accessibility, but also diminishes reliance on conventional freshwater resources.

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Turnip (Brassica rapa) cultivation, a dietary staple in numerous cultures and a pivotal element of diverse culinary customs, manifests particular sensitivity to soil conditions and water quality. The efficacious application of sunrays-treated saline water in turnip cultivation possesses the potential to revolutionize agricultural methodologies. By harnessing the advantages of treated saline water, farmers can optimize the management of their water resources while sustaining or potentially enhancing crop yields.

This research endeavor seeks to delve comprehensively into the intricate interplay between the application of sunrays-treated saline water and the augmentation of turnip yields. Through a thorough scrutiny of soil attributes, parameters governing plant growth, and nutrient absorption, our objective is to illuminate the underlying mechanisms driving the positive outcomes witnessed in turnip cultivation. Furthermore, this study aspires to provide pragmatic insights into the execution of this innovative approach, accentuating its potential contribution to the establishment of sustainable agricultural systems.

In summation, the exploration of sunrays-treated saline water application in the realm of turnip cultivation signifies a paradigmatic shift in agricultural practices. This study aspires to unearth the scientific underpinnings and practical ramifications of this approach, potentially paving the way for a future characterized by water-efficient, resilient, and fruitful turnip farming, as well as extending to other endeavors in crop cultivation. As we navigate the complexities of an ever-evolving world, the harnessing of natural processes to tackle agricultural predicaments not only serves as a testament to human resourcefulness but also stands as a pivotal stride in ensuring food security for forthcoming generations. The quality of water is poor in arid and semiarid regions because of insufficient rainfall to leach down the salts in irrigated agriculture (Chaibi, 2013). To avoid problems when using these poor-quality water supplies, there must be sound planning to ensure that the quality of water available is of best use but it seldom happen so. Some treatment means or technologies are required to minimize the water quality deterioration (Daniel et. al., 2009). Use of solar energy is considered an ideal and cheap option for the treatment of small quantities of water using natural sunlight. Solar radiation in poor quality water changes its characteristics with varying period of sun. The objective of present research was to characterize the effect of sunrays on water quality and understand its effect on crops.

2. MATERIAL AND METHOD

Experimental Design and Methodology for Improving Turnip Yield through Innovative Application of Sunrays-Treated Saline Water:

1. Turnip Variety Selection:

To ensure a comprehensive study, a widely cultivated high-yield turnip variety, namely Brassica rapa 'Purple Top White Globe,' was deliberately chosen. This particular variety is renowned for its adaptability to diverse soil and environmental conditions.

2. Preparation of Soil:

A representative soil sample was meticulously collected from the designated experimental area and subsequently characterized in terms of its physical and chemical attributes. Parameters such as pH, organic matter content, and nutrient levels were assessed. The soil was then conditioned to establish an optimal growth environment conducive to turnip cultivation.

3. Generation of Saline Water:

Various levels of salinity in water were achieved by dissolving precise quantities of common salts (sodium chloride, calcium chloride, magnesium sulfate) in fresh water. The tested salinity tiers encompassed 2 dS/m (low), 5 dS/m (moderate), and 8 dS/m (high). These particular levels were thoughtfully selected to emulate realistic conditions typically observed in regions affected by soil salinity.

4. Solar Radiation Treatment:

The saline water samples, meticulously prepared as specified, were deliberately exposed to direct solar radiation over a predetermined duration. The objective of this solar radiation treatment was to emulate natural solar desalination processes. Transparent containers holding the samples were positioned to receive sunlight for six hours daily throughout a three-week span.

5. Experimental Plots and Treatments:

The designated experimental area was meticulously subdivided into distinct plots, each allocated to a specific salinity treatment. An additional control plot was allocated for irrigation with conventional freshwater. Each unique treatment was meticulously replicated three times, thereby ensuring robust statistical significance.

6. Seed Planting and Irrigation:

Turnip seeds were deliberately sowed in organized rows within each designated plot, adhering to established recommended spacing guidelines. An irrigation schedule was meticulously established, taking into account local climate dynamics and systematic monitoring of soil moisture levels. Irrigation was meticulously administered using the corresponding treated saline water for each plot, alongside conventional freshwater for the control plot.

7. Collection of Data:

At regular intervals throughout the entire growth cycle of the turnips, a comprehensive collection of data was conducted. This encompassed precise measurements of parameters such as plant height, leaf area, root development, and overall plant vitality. Additionally, periodic collection of soil samples occurred to assess fluctuations in soil salinity, nutrient availability, and microbial activity.

8. Harvesting and Yield Assessment:

Upon achieving maturity, the turnip roots were meticulously harvested from each designated plot. Metrics such as quantity, size, and weight of the harvested turnips were meticulously recorded. These metrics offered valuable insights into the influence of sunrays-treated saline water on turnip yield and overall quality.

9. Statistical Data Analysis:

The meticulously gathered data underwent rigorous statistical analysis, employing advanced techniques including analysis of variance (ANOVA) and post hoc tests to accurately identify and understand significant distinctions among the various treatments. Additionally, correlations between differing salinity levels, soil characteristics, and turnip yield were meticulously explored.

10. Interpretation and Conclusions:

The outcomes of the study were systematically interpreted to acquire a deeper understanding of the tangible effects of applying sunrays-treated saline water on enhancing turnip yield. The intricate interplay between varying salinity levels and their potential ramifications on plant growth, nutrient assimilation, and soil health were thoughtfully discussed, underscoring their significance within real-world agricultural scenarios.

Through the meticulous execution of this extensive experimental design and methodology, the study earnestly aimed to provide invaluable insights into the pragmatic feasibility of utilizing sunrays-treated saline water to bolster turnip yield. The deliberate selection of distinct salinity levels significantly contributes to the study's replicability and bolsters the applicability of its findings across a diverse array of agricultural contexts. This, in turn, reinforces the study's pertinence and its capacity to contribute meaningfully to the advancement of sustainable agricultural practices. An experiment was conducted to study the impact of sun rays on water quality and crop yield during pot study in the laboratory (Figure 1). The experimental setup consisted of 02 Plexiglas/storage tank covered with transparent sheet, 08 plastic bottles for water sampling and 18 pots for Turnip plant growth studies. Eight bottles were used for sampling. Low saline level and fresh water (ground water) were collected in these bottles and placed under sunlight for 6 hours in a day. Samples were taken from bottles before and after solar treatment and laboratory analysis were performed to examine the physiochemical changes in water quality parameters. Parameters like seedling growth, root depth, No. of leaves and height of plants were measured during experimentations. Water use efficiency was also determined for Turnip crop.

Figure. 1. Experimental pots study with low saline and fresh water

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3. RESULTS AND DISCUSSION

3.1. Water quality parametres

Enhancing Turnip Yield through Innovative Sunrays-Treated Saline Water Application: Comprehensive Examination and Discourse on Findings

In tandem with investigating the effects of sunrays-treated saline water on the augmentation of turnip yield, this study meticulously explored the ramifications of solar radiation on the quality attributes of saline water in comparison to conventional freshwater. A systematic evaluation encompassing parameters such as Electrical Conductivity (EC), pH, cations, anions, and Sodium Absorption Ratio (SAR) was meticulously conducted to unravel the transformations brought about by solar radiation treatment. The ensuing sections present a thorough interpretation and discourse of these findings, enriched by statistical analyses and contextualization within the existing scholarly corpus.

Quality Parameters of Irrigation Water:

The scrutiny of irrigation water quality parameters has unveiled captivating insights into the sway exerted by solar radiation upon the characteristics of saline water vis-à-vis freshwater. Precisely, meticulous examination was directed toward the fluctuations in pH, EC, and chloride (Cl) content both before and subsequent to the solar treatment.

Shifts in pH and EC:

The pH of the water exhibited marginal variations post solar treatment, albeit sans conspicuous prominence. Remarkably, a reduction in pH of approximately 4.2% was noted in the case of low saline water, while an analogous decline of 3.5% was detected in freshwater. This subdued modulation in pH resonates with precedent research indicating the limited influence of solar radiation on pH alterations.

Furthermore, the pivotal indicator of water salinity—Electrical Conductivity (EC)—manifested adjustments consequent to solar treatment. A discernible reduction of approximately 4.05% was ascertained in low saline water subsequent to treatment. This phenomenon could conceivably be attributed to the prospective desalination effect induced by the radiant energy of the sun. These nuanced fluctuations warrant attention as they furnish insights into the intricate interplay between solar radiation and the ion composition intrinsic to treated water.

Chloride (Cl) and Total Dissolved Solids (TDS):

Curiously, chloride (Cl) evinced only minor modulations in both low saline water and freshwater subsequent to solar treatment. While the Cl content maintained a semblance of stability, an elevation in Total Dissolved Solids (TDS) was observed in the context of low saline water, escalating from 830 (meg/l) to 895 (meg/l) post-treatment. This discernible surge in TDS may signify salt accumulation engendered by the concentration effect brought about through solar evaporation. A comparable albeit milder TDS alteration of 23 (meg/l) was documented in freshwater, thereby spotlighting a subtler interplay between solar radiation and the water's ion composition.

Cations and Anions:

The exploration of variances in cations (namely, Calcium, Magnesium, and Sodium) as well as anions (encompassing Carbonates and Sulfates)—both pre and post solar treatment—yielded noteworthy insights. A conspicuous attenuation in Calcium and Magnesium ions was observed subsequent to treatment, potentially alluding to their precipitation owing to the altered physicochemical conditions triggered by solar radiation. Sodium, conversely, displayed inconspicuous shifts in both water types. Meanwhile, the Sodium Absorption Ratio (SAR) exhibited an upward trend in both low saline water and freshwater. The elucidation of the precise catalysts underpinning this SAR escalation necessitates further rigorous exploration and scrutiny.

Comparative Analysis and Practical Implications:

The findings of this inquiry seamlessly dovetail with the existing body of scholarship underscoring the propensity of solar radiation to evoke subtle adjustments in water quality parameters, particularly pertaining to pH and EC. While the influence of solar radiation on pH was discernibly restrained, the contraction in EC subsequent to treatment in low saline water hints at plausible desalination, which holds momentous implications for regions beleaguered by soil salinity.

The observable elevation in TDS, especially in low saline water, accentuates the significance of meticulous TDS monitoring within saline-affected domains when contemplating the adoption of solar radiation as a remedial modality. The regression in Calcium and Magnesium ions, coupled with the observed SAR surge, underscores the necessity for in-depth inquiry to elucidate the latent mechanisms and repercussions.

To conclude, albeit the impact of solar radiation on water quality parameters may be nuanced, the resultant findings proffer indispensable insights for agricultural stakeholders and scholars alike. By assimilating the subtle shifts wrought by solar radiation, decision-makers can cultivate an informed outlook when evaluating the application of sunrays-treated saline water in the sphere of turnip cultivation and allied agricultural pursuits. The contributions of this study extend beyond the amplification of turnip yield, embracing a broader vista encompassing sustainable water resource governance and agricultural resilience amidst the transformative dynamics of the environment.

Irrigation water quality parameters such as EC, pH, Cations, Anions and Sodium Absorption Ratio were used to study the impact of solar radiation on the quality parameters of saline water in comparison with fresh water as presented from Table 1 to Table 3.

Table 1 presents the values of pH, EC and Cl of low saline water and fresh water before and after the treatment with sun-rays. It has been noted that solar radiations changes the pH of water after solar treatment but the effect is not significantly pronounced. However a reduction in pH of water in low saline was found to be 4.2% and it was 3.5% in case of fresh water after solar treatment. EC also changes similarly and found reduction to the tune of 4.05% in low saline water after treatment. Cl has minor changes in low saline water and fresh water after apply treatment of sun-rays. Total dissolved solids has been increased from 830 (meg/l) to 895 (meg/l) in low saline water after applying solar treatment. This may be accumulation of salts in the water after application of solar energy.

Similarly a difference of 23 (meg/l) was noted in fresh water. Carbonates have no significant effect after applying the solar treatment and SO_4as well "Table 2". Table 3 indicates that Calcium-Magnesium ions values decreased after the treatment. Sodium has minor changes in both types of water and SAR showing increasing trending in low saline water as well as fresh water due to unknown reasons. As a whole, it can safely conclude from the present study that solar radiation have minor influences in changing the water quality parameters of both low saline and fresh water.

Table 1. pH, EC and Cl of low saline water and fresh water after solar treatment

Sr. No.	Type of Water Applied	pH (meq/L)		EC (dsm^{-1})		Cl (meq/L)	
		Before Solar Treatment	After Solar Treatment	Before Solar Treatment	After Solar Treatment	Before Solar Treatment	After Solar Treatment
1	Low Saline Water	7.93	7.59	2.14	1.93	4.21	3.89
2	Fresh Water	6.74	6.5	0.75	0.65	3.99	3.77

Table 2. TDS, HCO3 and SO4 of low saline water and fresh water after solar treatment

Sr. No.	Type of Water Applied	TDS (meq/L)		HCO_3 (meq/L)		SO_4 (meq/L)	
		Before Solar Treatment	After Solar Treatment	Before Solar Treatment	After Solar Treatment	Before Solar Treatment	After Solar Treatment
1	Low Saline Water	830	895	2.21	2.15	4.03	3.93
2	Fresh Water	460	483	1.79	1.75	2.69	2.61

Table 3. Ca+Mg+, Na and SAR of low saline water and fresh water after solar treatment

Sr. No.	Type of Water Applied	Ca+ Mg+(meq/L)		Na (meq/L)		SAR (meq/L)	
		Before Solar Treatment	After Solar Treatment	Before Solar Treatment	After Solar Treatment	Before Solar Treatment	After Solar Treatment
1	Low Saline Water	6.67	6.36	31.5	32.4	4.69	5.55
2	Fresh Water	6.23	6.03	3.32	3.82	3.28	3.85

3.2. Turnip yield indicators and water productivity

Table 4 presents the plant growth parameters of Turnip and water productivity both under solar treated low saline water and fresh water during pot study in the laboratory. It can be noted from the table that fresh water has significant effect on the growth parameters compared with low saline water treated with sun rays.

Table 4. Values of physical measurements after application of treatments

Type of water applied	Plant Height	No. of Leaves	Root Depth	Yield	Water productivity
	(inch)	(No.)	(inch)	(g)	(g/L)
Low saline water under sun light	9	11	4.2	1140	19
Fresh water application	12	13	5	1510	25.16

On the average, the application of fresh water produces plant height to the tune of 12 inches, number of leaves upto 13 and root depth upto 5 inches compared with the low saline water treated with sun rays under similar conditions. The results showed that plant height and amount of biomass increases by fresh water application against solarized water treatments in case of turnip crop significantly. These results were in accordance with the findings of Rahman et al. (2008), Usman Khalid and Nasir (2012) and findings by Morsy (2002). Fresh water application showed maximum yield 1510 g/l compared with low saline water application under sunlight as 1140 g/l. These results showed that fresh water application increases the plant growth and ultimate yield against low s/w application under sunlight in case of turnip crop significantly. These results were in accordance with the study conducted by Khan et al. (2008).

4.CONCLUSION

Significant Conclusions:

1. Solar Radiation and Water Quality: Through an exhaustive exploration of the impact of solar radiation on the quality of saline water, this study underscores that solar radiations exert minimal influence on altering water quality parameters, encompassing both low saline and fresh water. While subtle variations in pH and electrical conductivity were noted, these alterations suggest a restrained effect of solar radiation on water quality.

2. Turnip Growth: Scrutiny into turnip growth accentuated the potential advantages of utilizing fresh water in comparison to low saline water treated with solar rays. Application of fresh water manifested in taller plant stature, increased leaf abundance, and deeper root development—indicative of water quality's role in augmenting turnip growth within controlled conditions.

3. Yield and Productivity: The findings intimate that water quality, influenced by solar radiation treatment, subtly impacts yield and productivity indicators encompassing plant height, leaf count, root depth, and water-use efficiency. While the impact isn't dramatic, it underscores water quality's significance in optimizing crop growth.

Guidelines for Agricultural Enhancement:

1. Contextual Implementation: While solar radiation treatment displayed marginal alterations in water quality attributes within laboratory settings, its pragmatic deployment warrants evaluation within real-world agricultural contexts, duly considering a spectrum of environmental variables, soil conditions, and crop diversities.

2. Strategic Irrigation Management: The potential benefits of utilizing solar radiation-treated water to bolster crop growth warrant further examination into optimal irrigation strategies. Tailoring irrigation schedules to capitalize on subtle growth enhancements could contribute to ameliorated crop yields.

3. Safeguarding Soil Health: Acknowledging nuanced shifts in ion composition, prudent soil management practices should accompany the adoption of solar-treated water. Consistent monitoring and soil adjustments can mitigate potential long-term repercussions on soil well-being.

4. Holistic Sustainability Frameworks: The assimilation of solar radiation-driven water treatment into comprehensive sustainability frameworks holds the promise of optimizing resource utilization, enhancing agricultural resilience, and amplifying yield capacities. This integration contributes to a more sustainable and thriving agricultural ecosystem.

In essence, while solar radiation's direct influence on water quality may be understated, the cumulative effect on crop productivity and agricultural sustainability is noteworthy. By adeptly harnessing solar potential for water treatment and irrigation, agriculture can stride confidently into a future marked by sustainability and abundant prosperity.

Conclusions drawn from the present study describe the influence of solar radiation on saline water quality and Turnip growth under laboratory conditions. Yield and growth indicators were also noted that includes plant height, number of leaves, root depth and water productivity. Water quality analysis concluded that solar radiations have minor influences in changing the water quality parameters of both low saline and fresh water. The application of fresh water produces plant height to the tune of 12 inches, number of leaves upto 13 and root depth upto 5 inches compared with the low saline water treated with sun rays.

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Conflicts of Interest: All authors declare no conflict of interest and no any problem regarding the article.

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A Comparison of Image Classification on Synthetic Aperture Radar and Optical Images for Detection of Water Bodies: Case of Lake Burdur, Türkiye

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Abstract

This study presents a comparison of the classification results of two different datasets using two individual methods. This study utilizes both sentinel-1 data and Landsat data, with the first method involving the application of image classification on the sentinel data obtained and comparing the results. Additionally, data fusion as a second method was also performed on the sentinel VV polarisation and VH polarisation with Landsat 8 bands 3,5 and 8 in an attempt to improve the accuracy results of the classification. The classification results of the first method and the second method are compared in this paper. Water detection was the primary goal of this study, leading to these specific choices of Landsat bands.

Keywords: Water body detection; image classification; synthetic aperture Radar; optical imagery; image fusion

1. INTRODUCTION

The majority of Earth's surface is covered with water and it is an important subject to the interest of people (Wang et al., 2011) as productive and ecologically diverse ecosystems are located along these water bodies, however, the extent of these bodies is getting smaller each year at alarming rates (Huang et al., 2018). Accurate assessment and analyses of the spatial extent of water bodies over time play a crucial role in monitoring the effects of climate change and show how this phenomenon is affecting the environment, ecology as well as water resources. Applications of Remote Sensing are widely used for these analyses since they provide advantages such as broad observation areas, short time periods of observation and easy acquisition of necessary information from areas of interest (Fu et al., 2007).

SAR systems have shown their abilities for countless Earth observation applications (Krieger et al., 2010) since they provide high-resolution and two-dimensional images which are not dependent on daylight, cloud coverage and various weather conditions (Moreira et al., 2013). In addition to these, they are very sensitive to open water so they are utilised for water surface detection (Huang et al., 2018). Despite all these advantages, SAR data has limited availability (Santoro et al., 2015) and this causes discontinuities in spatial and temporal data. Moreover, analysis of SAR data can be complicated which can lead to misinterpretation. complications of using SAR data, improving classification accuracy (L. et al., 2009).

Fusion of different sensors which can detect different aspects of water bodies and their surroundings, can be a solution to overcome the This paper focuses on comparing the classification outputs provided by the multiple data sources, the sources used were Sentinel-1 and Landsat-8 data. Data fusion methods were used on these data to improve classification results.

2. STUDY AREA

The area chosen for this study is Lake Burdur which is among the largest and deepest lakes in Turkey and is located at the southwest. It is a tectonic and a closed basin lake located between Burdur and Isparta provinces and it has 250 km^2 of water surface. As well as its distinguished size, it has great ecological importance since it is a habitat for globally threatened bird species (RAMSAR).

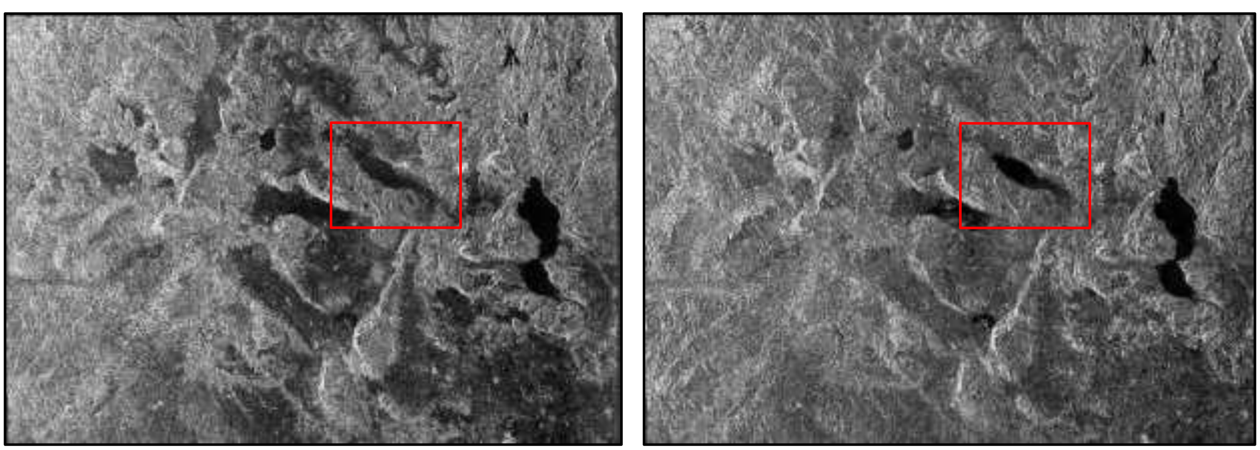
Figure 1. Location of the Study Area (www.earth.google.com)

1. DATASET

For extracting the water extent of Lake Burdur, two Sentinel-1A and one Landsat-8 data from November 2022 were used. C band Sentinel-1 Ground Range Detected (GRDH), Interferometric Wide (IW), dual polarimetry (VV and VH mode data were acquired with) descending pass direction. In addition to the SAR data, the three bands that present the water surface the best of all the Landsat bands were green, red and panchromatic.

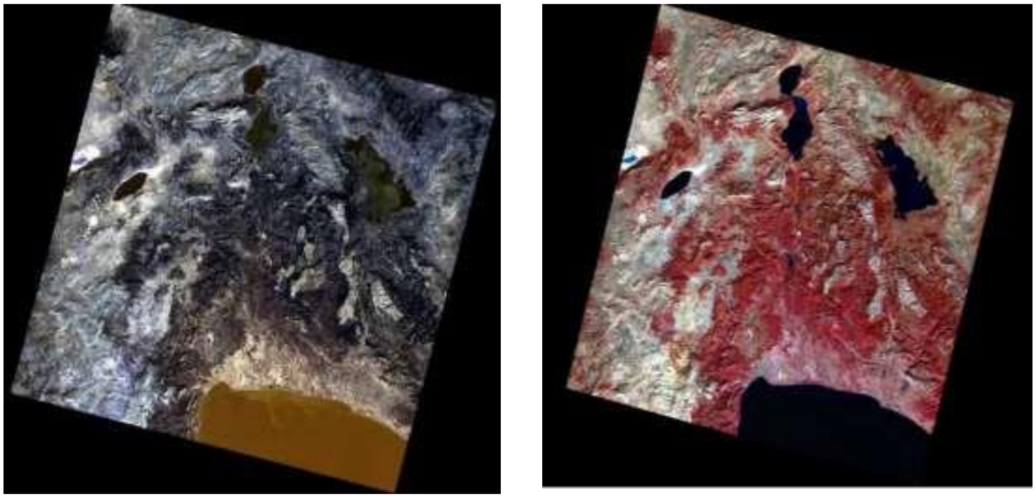
Table 1. Characteristics of Sentinel-1 and Landsat-8 Data

Sentinel-1	**Acquisition Date**	**Polarization**	**Pass Direction**	**Mode**
	20.11.2022	VV-VH	Descending	IW GRDH
Landsat-8	**Acquisition Date**	**Spectral Resolution**	**Spatial Resolution**	**Temporal Resolution**
	14.11.2022	Multispectral: 0.43-0.67 µm	15 m (Panchromatic)	16 days
		IR: 0.85-2.29 µm	30 m (Multispectral)	
		Pan: 0.50 – 0.68 µm	100 m (Thermal IR)	
		Circus: 1.36 – 1.38 µm		



(a) (b)

Figure 2. Sentinel-1 scene acquired on 20 November 2022, VH polarization (a), VV polarization (b) and the location of the study area



(a) (b)

Figure 3. Concatenated Landsat-8 image with bands 3, 5, 8 (Green, NIR, Panchromatic) (a), false colour image (NIR, Red, Green) (b)

2. MATERIALS AND METHODS

The workflow of the process chain, as can be seen in Figure 4, is composed of the following steps; pre- processing of sentinel images, landsat-8 and sentinel-1 data fusion, classification of sentinel-1 and fused data using random forest classifier and accuracy assessment of the results. To be able to perform the mentioned steps Sentinel Application Platform (SNAP), QGIS and Monteverdi software were used.

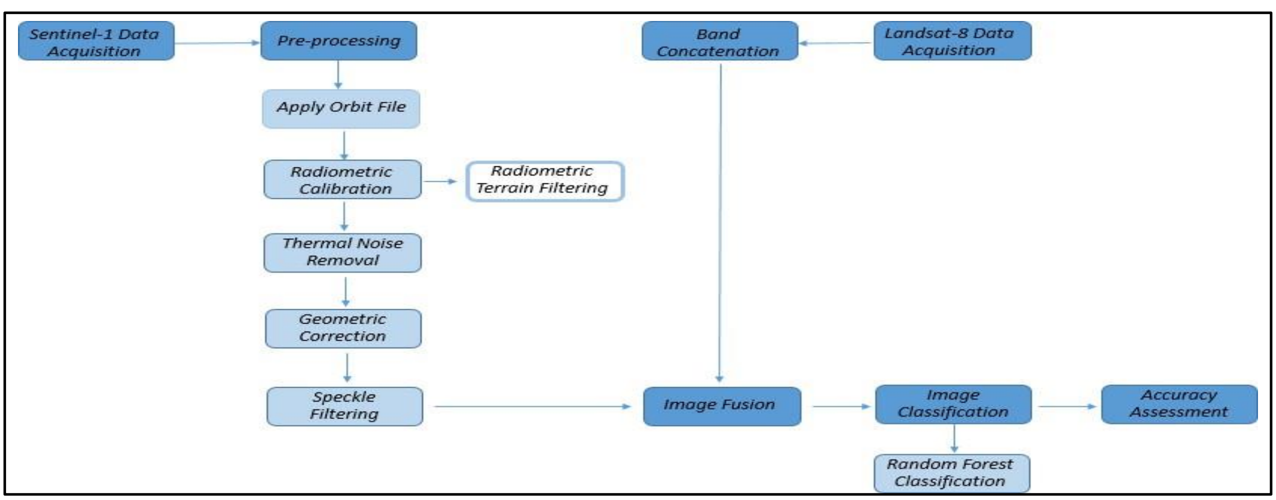


Figure 4. Workflow of the Process Chain

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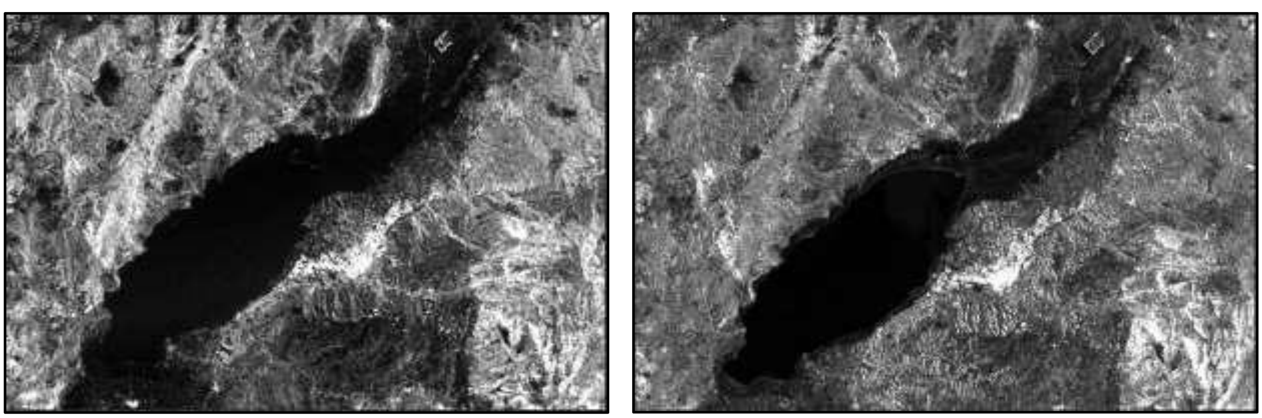
2.1. Pre-processing of the Data

Pre-processing of the Sentinel-1 data was conducted on SNAP software for each VV and VH modes and the process was initialised by using Apply Orbit File (AOF) to improve geocoding results. Radiometric calibration was applied next to correct the signal intensity. Radiometric Terrain Flattening was performed then to remove the topographic effect from the study area. Next, thermal noise needed to be removed and the Thermal Noise Removal command was used for this purpose. After applying radiometric corrections, geometric correction of the image needed to be conducted. This was performed by Range- Doppler Terrain Correction and images were projected into the Universal Transverse Mercator (UTM) or World Geodetic System 1984 (WGS84) together with the corrections of distortion effects such as shadow or layover, which occurred during the acquisition. Radar images produced some noise called speckle and to enhance the quality of the data speckle filtering operation was needed to be used. Before filtering the image, the study area was clipped to reduce the required processing time of filtering, and then by using Lee Filter 7x7, the effects of speckles were reduced.

For the Landsat image, the three bands that present the water surface the best of all the Landsat-8 bands which were green, red and panchromatic were concatenated using Monteverdi software, then it was clipped using the same coordinates as the corners for each image.



(a) (b)

Figure 5. Post-processed Sentinel-1 image, VH polarization (a), VV polarization (b)

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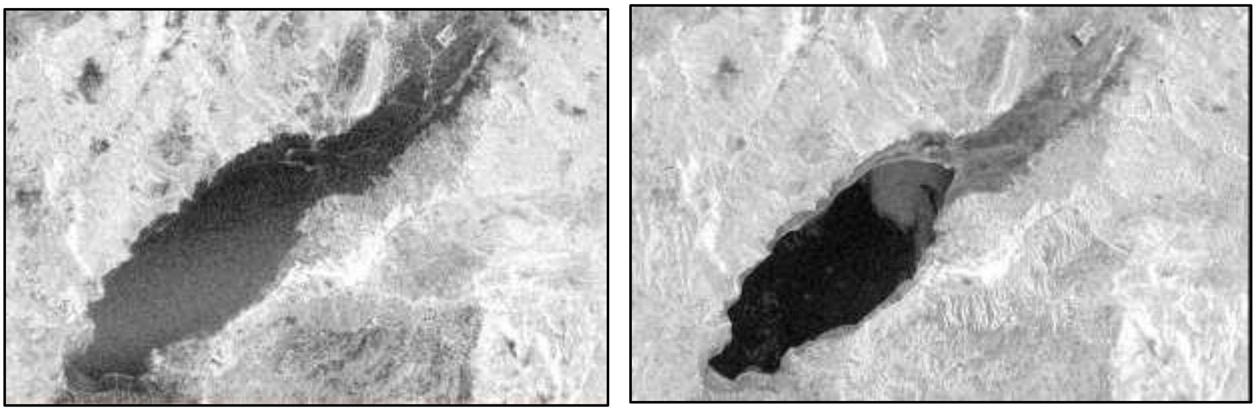

(a) (b)

Figure 6. Post-processing images of SAR data converted from linear (sigma values) to decibels, VH polarization (a), VV polarization (b)

(a) (b)

Figure 7. Clipped Landsat-8 image with bands 3, 5, 8 (Green, NIR, Panchromatic) (a), false colour image (NIR, Red, Green) (b)

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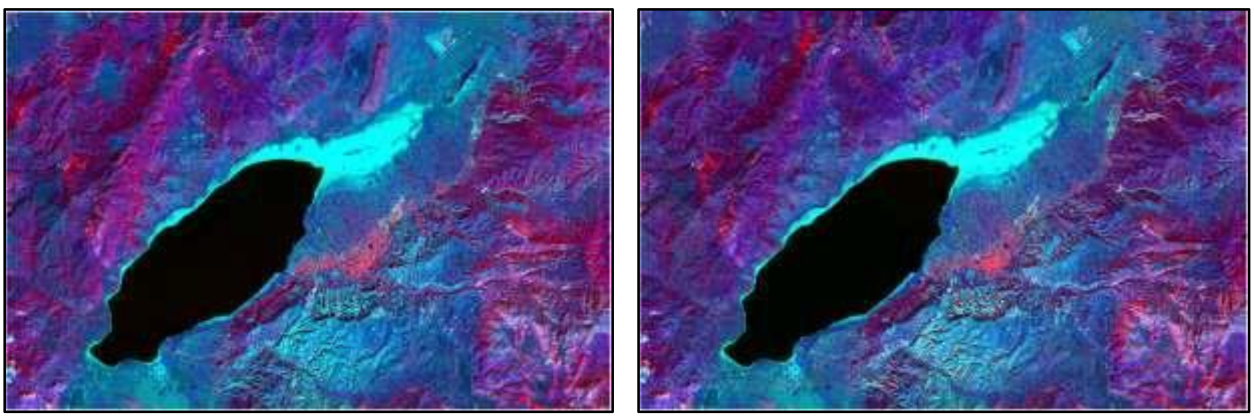
2.2. Image Fusion

Image fusion is a technique used to combine the geometric detail of a panchromatic image having a high spatial resolution and the colour information of a multispectral image having a low spatial resolution to create a high-resolution multispectral image (Quang et al., 2019). For this study, a fusion of the images was created using sentinel-1 as high resolution and Landsat image as coloured data so that a high-resolution multispectral image would be obtained. The image concatenation tool from the Monteverdi application was used as the method for this. Bands 3,5 and 8 were taken from the Landsat image and concatenated with the sentinel VV image, and then again with the sentinel VH image. Bands 3 (green) and 5 (NIR) were chosen for the Landsat image as these bands differentiate water more clearly from other objects. Furthermore, Band 8 (panchromatic) was chosen to add extra special details such as the extent of the water.



(a) (b)

Figure 8. Landsat-8 bands 3,5 and 8 fused with VH sentinel data (a), Landsat-8 bands 3,5 and 8 fused with VV sentinel data (b)

Fusing these Landsat and sentinel (VV, VH) data sets created two separate high-resolution images suitable for classification.

2.3. Image Classification

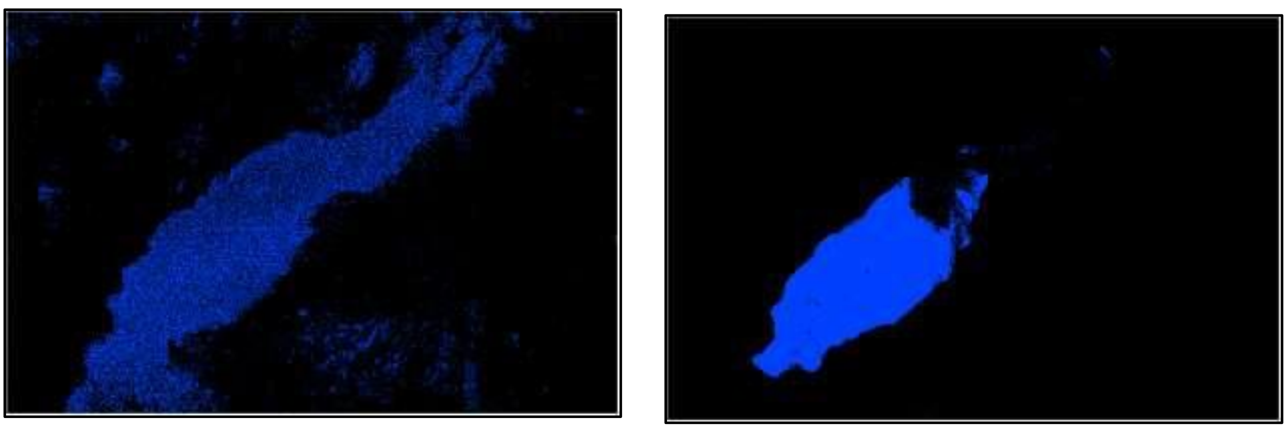
Random forest classification has proven to be a reliable and effective alternative to other regular pixel-based classifications and is specifically useful for classifying satellite imagery. It is seen as one of the most successful classification methods in the community (Bayik et al., 2018). The classification was carried out on the sentinel VV data and the sentinel VH data separately, as well as the sentinel VV fused with the Landsat data and the sentinel VH fused with the Landsat data. The semi-automatic classification plugin (SCP) in QGIS was used to perform the classification.

Training classes were created as polygons covering the required areas, only two main classes were created, these being 'water' and 'other'. The 'Other' class had multiple different subclasses which were created to help define the main class more accurately and hopefully cancel out any misclassification of water.

2.4. Accuracy Assessment

Once again, the SCP extension in QGIS was used for calculating the accuracies of the classifications. A separate validation layer using the same classes was created. This layer covered separate areas to the classification training data and, since there was no access to ground truth data, each polygon in the validation set was assigned to a class based on looking at the image. The accuracy assessment tool was used with the validation layer being used on the classification raster. This process was carried out on each classification output, with the same validation layer was used for each one.

3. RESULTS AND CONCLUSIONS



(a) (b)

Figure 9. RFC classification of sentinel VH data with water as blue and non-water as black (a), RFC classification of sentinel VV data with water as blue and non-water as black (b)

From visual inspection, it can be seen that the classification of VH data performed poorly compared to that of the VV data, with the VH classification causing misclassifying lots of non-water areas as water.

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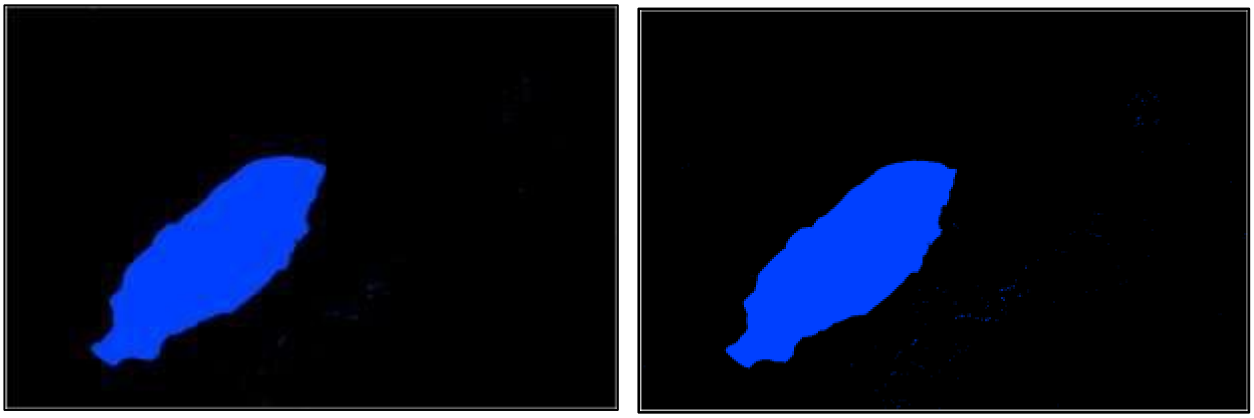

(a) (b)

Figure 10. RFC classification of fused sentinel VH with Landsat data with water as blue and non-water as black (a), RFC classification of fused sentinel VV with Landsat data with water as blue and non-water as black (b)

From visual inspection, it can be seen that both VH and VV sentinel data fused with Landsat data provides a very accurate water extent with minimal misclassification.

From visual inspection of the Random Forest classifier outputs, it was observed that the classifications made on both sentinel-1 data sets did not show the correct water extent. The classification was performed slightly better when VV mode was used as the input raster, compared to VH mode. When fused data was classified, however, very accurate visual results were observed. These findings were further supported by the histograms showing the decibel backscatter values for both VV and VH polarisations.

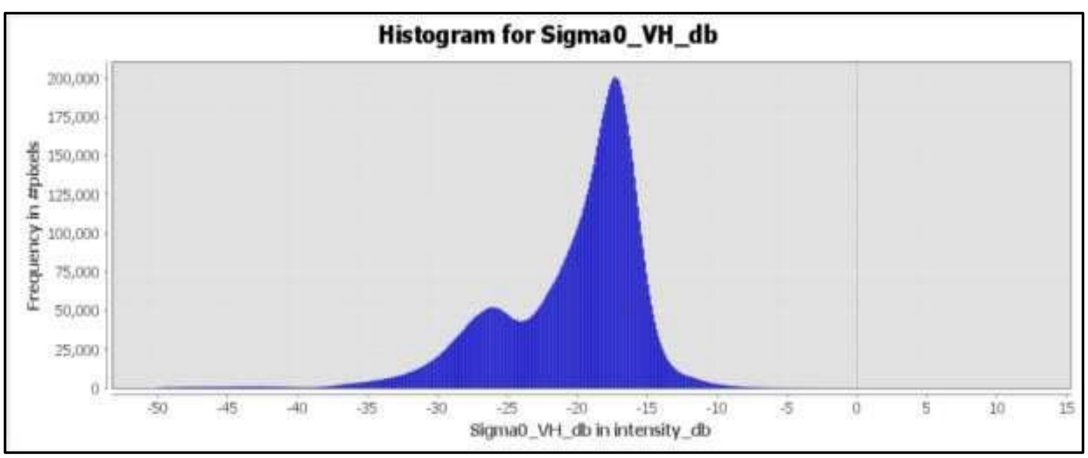

Figure 11. Histogram showing the backscatter values of the VH SAR image.

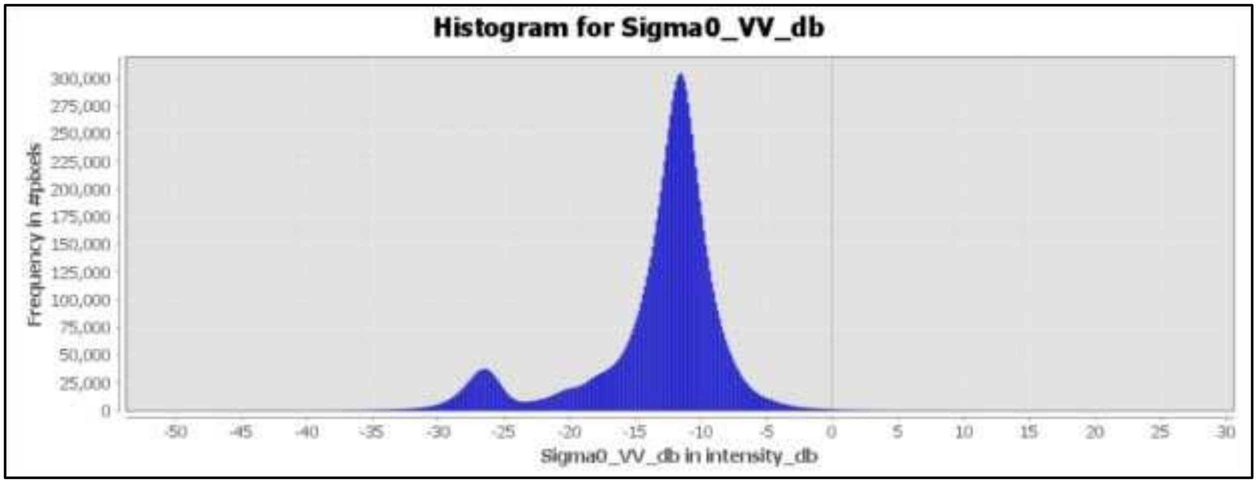

Figure 12. Histogram showing the backscatter values of the VV SAR image.

In both histograms, there are two peaks present with each peak representing different surface types according to their backscatter value. The smaller peak represents water with the larger peak representing other land covers such as vegetation, bare land, urban, etc. Water pixels are normally supposed to have a backscatter value of roughly -24 db. After examining the individual pixel values of the image, for this case water values were found to be between -32 db and -24 db for the VV polarisation and -24 db and -36 db for VH polarisation.

Table 2. Accuracy table for classification of Sentinel VH image

Sentinel_VH	Water	Other	Total
Water	273990	94630	368620
Other	242430	1779675	2022105
Total	516420	1874305	2390725
Producers Accuracy [%]	44.1047	96.4205	
Users Accuracy [%]	74.3286	88.011	
Overall Accuracy [%]	86.4662		
Kappa	0.4799		

The table above shows the classification accuracy results of the VH sentinel nonfused image. Producers' accuracy for the 'water' class is 44% whereas users' accuracy for water was 74%. The overall accuracy was calculated as 86% with a low kappa coefficient value of 0.48.

Table 3. Accuracy table for classification of Sentinel VV image

Sentinel_VV	Water	Other	Total
Water	393776	4051	397827
Other	122644	1870254	1992898
Total	516420	1874305	2390725
Producers Accuracy [%]	60.4152	99.8971	
Users Accuracy [%]	98.9817	93.8459	
Overall Accuracy [%]	94.291		
Kappa	0.7202		

The table above shows the classification accuracy results of the VV sentinel nonfused image. Producers' accuracy for the 'water' class is 60% whereas users' accuracy for water was 99%. The overall accuracy was calculated as 94% with a moderate kappa coefficient value of 0.72.

Classification using VV data gave better overall accuracy than that of the VH data, with the overall accuracy for the VV classification being 7.8448% higher than that of the VH classification. VV also produced higher users and producers' accuracy, as well as having a higher kappa coefficient. Notably, the producer's accuracy for water seems to be relatively low across both polarisations, which has led to a lower kappa coefficient across both classifications, especially the VH image. Despite this, users' accuracy remained relatively accurate for both data sets. Furthermore, the results line up with the visual representation of the classification, wherein the classification of VH data misclassified large portions of the area.

Table 4. Accuracy table for classification of Sentinel VH image fused with Landsat bands 3,5 and 8

Sentinel_VH/Landsat	Water	Other	Total
Water	516420	1259	517679
Other	0	1873046	1873046
Total	516420	1874305	2390725
Producers Accuracy [%]	100	99.9744	
Users Accuracy [%]	99.7568	100	
Overall Accuracy [%]	99.9769		
Kappa	0.9987		

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The table above shows the classification accuracy results of the VH sentinel image fused with Landsat data. Producers' accuracy for the 'water' class is 100% whereas users' accuracy for water was 99.7568%. The overall accuracy was calculated as 99.9769% with a high kappa coefficient value of 0.9987.

Table 5. Accuracy table for classification of Sentinel VV image fused with Landsat bands 3,5 and 8

Sentinel_VV/Landsat	Water	Other	Total
Water	516420	1151	517571
Other	0	1873154	1873154
Total	516420	1874305	2390725
Producers Accuracy [%]	100	99.9753	
Users Accuracy [%]	99.7776	100	
Overall Accuracy [%]	99.9778		
Kappa	0.9988		

The table above shows the classification accuracy results of the VV sentinel image fused with Landsat data. Producers' accuracy for the 'water' class is 100% whereas users' accuracy for water was 99.7776%. The overall accuracy was calculated as 99.9778% with a high kappa coefficient value of 0.9988.

Classification of the fused images showed much closer overall accuracy results as well as much closer producers' and users' accuracies across the classes, leading to high kappa coefficients. Overall accuracies were over 99%, showing very high levels of classification across both VV and VH data, nevertheless, the fused VV data showed a very slightly higher accuracy result than that of the VH data.The fused images in conjunction with the random forest classifier produced the highest accuracy results, specifically the fused images using the sentinel VV data.

The most accurate results of all classification outputs were shown to be the fused sentinel and Landsat images in conjunction with the RFC. The sentinel images by themselves did not show very accurate results and caused misclassification of land areas as water. This could be due to the fact that the images were obtained in November which is a rainy season in Lake Burdur, causing the moisture in land areas to be detected by the SAR sensors. This however was not a problem for Landsat data. That is why sentinel images showed relatively poor accuracy results compared to the fused images.

To improve the use of using sentinel data exclusively in potential future research, time series data can be used to improve the classification results of SAR data. This can be useful in situations that Landsat data cannot be acquired, for example, bad weather conditions.

While VH is more effective at detecting rough surfaces due to the depolarisation effect of volume scattering (Amazirh et al., 2018), VV is much more efficient at differentiating water from surrounding surfaces and vegetation (Twele et al., 2016). This can be seen just from the visuals of the SAR images. The VV image shows that Burdur Lake stands out and is much more defined in contrast with the surrounding areas, whereas in the VH image, some areas surrounding the lake are much less defined and look similar to the water.

In the VH non-fused image, some areas are much less defined and look similar to the water, they look as if they have low backscatter values similar to the water surfaces. This is backed up by the low overall accuracy of the VH image classification. Furthermore, VH polarised data could have led to a very low land-water contrast, resulting in a higher amount of misclassifications. Not only were some areas misclassified as water, but some for the actual water surface, wrong results were still being produced. This can be seen as parts of the lake are classified as 'other', rather than 'water'. The VH data also caused misclassification in a large portion of agricultural farmland southwest of the lake, due to the low polarisation and low backscatter value in VH polarisation (Twele et al., 2016). VH polarisation created water-lookalike areas due to these effects.

This can be seen with the backscatter values for the VH polarisation not differentiating water from land as well as the VV. This can be seen in Figure 11 with the histogram showing the backscatter values for VH polarisation. It is observed that there is a much smoother transition between both peaks in the VH histogram meaning that water and other land covers are less distinguished from each other. The opposite can be seen in Figure 12 which shows the VV backscatter values histogram, as can be seen there, there is a much sharper curve between the two peaks, signifying that there is more differentiation between water and other land surfaces.

As can be seen in the classification of the non-fused VV image, there was an area of water that was misclassified as other in the northeast portion of the lake. This is due to the slightly higher backscatter values of the water in this area, with most pixels having a rough value of -18 which is a value associated with forests, paths, roads, etc. This area can be seen as brighter in Figure 6 showing the SAR images backscatter decibel values. This could be due to this area being shallower in water depth than other areas of the lake since C band VV and VH polarisation have been shown to be sensitive to water depth (Zhang et al., 2022).

Overall, VV sentinel data fused with Landsat bands 3,5, and 8 showed the highest accuracy results as expected. This is mainly due to the fact that, as previously discussed, VV data is much better at differentiating water from surrounding areas when compared to VH data. In addition, the Landsat bands chosen were specifically chosen as they extract water from images with the highest effectiveness leading to higher accuracy of the fused images instead of just the sentinel images by themselves.

SAR data by itself is very useful for gathering data in certain conditions and is a powerful tool in identifying land cover, however, it still has its flaws and classification on a single polarisation by itself will not lead to accurate results. The SAR data in combination with optical images has shown a much higher accuracy in classification once fused together. This study in particular focused on water and thus selected the polarisations and bands that were most suitable for the extraction of water surfaces, but this principle of fusing can still be applied to other classification problems using other bands in order to increase classification accuracy.

4. References

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