ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.04 No.01 (2026)

WASTEWATER IRRIGATION: A SYSTEMATIC REVIEW OF FARMER PERSPECTIVES, SOCIO-ECONOMIC DRIVERS, AND HEALTH OUTCOMES

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Abstract
In developing countries, mostly those countries who have poor wastewater treatment facilities used untreated reused water as a popular practice of irrigation. In Pakistan, climate change is a problem of main concern and its many semi-arid and arid areas are facing water shortage. That's why the country's one of the common practices is using wastewater for irrigation. Wastewater, specifically industries and households' wastewater, is used for agriculture in Pakistan. The drive of this review paper is to explore the farmers perspectives towards wastewater irrigation on the base of various previous researches. To fulfill the purpose of the study, by analyzing recent peer-reviewed literature (2000–2022), various articles, reports and book chapters by a holistic approach, the information based on the farmers' perspectives of wastewater irrigation was gathered. This article concludes by summarizing current knowledge in this area and offering advanced recommendations to enhance understanding of key wastewater irrigation topics.

Keywords: *Wastewater irrigation, farmers' awareness and knowledge, health impacts, socio-economic factors*

1 Introduction

Water pollution and scarcity of water are two of the most known global challenges that people are facing and nonconventional resources of water are proposed to cover this gap among them. Clean freshwater is limited for crop irrigation and it is in competition with the demand for household and industrial consumption (EC, 2000). Consequently every year about 4.36 billion m^3 (BCM) reused water including industrial and household wastewater is generated, in which 1.30 BCM from industries and 3.06 BCM from household. Before disposing out of wastewater, its not even 1% of the total wastewater gets treated till now and without any treatment about 1.02 billion m^3 of the wastewater is used for irrigation. Every year municipal wastewater is used to irrigate about 32,000ha of agricultural land and annually around 1.43 billion m^3 of municipal wastewater without any treatment disposed off into rivers. Around the world, wastewater irrigation is very common practice now to produce market-oriented crops such as pulses, cereals, oilseeds and vegetables and this practice is very common in about 200 million farmers (Pratap et al., 2021). The contaminated water is leading to an annually deaths of children and according to a study this death rate by water born diseases is 250,000 children including mostly less than five years age group. Pakistan is facing water challenges and its status has been changed from water abundant to water stress country. Between 1990 and 2015, per capita water

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availability is decreasing to 1,306 cubic metres per inhabitant from 2,172 cubic metres per inhabitant. Pakistan annually extracts 74.3 percent of its fresh water so employing absurd pressure upon renewable water resources. Despite outstanding developments in the proportion of population using better source of water and better-quality sanitation facility, however Pakistanis do not have access to safe drinking water and proper sanitation sanitation that is 27.2 million and 52.7 million respectively. In Pakistan, due to diarrhea children under the age of five total 39,000 children caused by unsafe water and poor sanitation, out of which 88 percent is attributed to inadequate sanitation and hygiene and unsafe water supply (WHO, 2015; DAP, 2016).

Water shortage is becoming a serious global issue. The reasons behind the water shortage are rapid population growth and socio-economic development. Wastewater can be used in agriculture as a key substitute to water resources and it compensates for the water shortage. In under developing and developed countries, wastewater irrigation has experienced different phases and has a long development history. Numerous environmental problems are core causes of untreated wastewater irrigation with. Use of wastewater in agriculture destroys soil quality and exerts various worsened impacts on environment and cause numerous problems in humans related to their health through wastewater irrigated crops (Zhang and Shen, 2017). In developing countries, many cities are generating waste that is disposed of without treatment into rivers afterwards farming community used it for irrigation. Though wastewater irrigation has many positive affects including which consistent water supply to farmers, better yield etc but many risks are associated with it such as health risks to farmers and cause chemical pollutants in soils and it is a way to contaminate the groundwater (Kunhikrishnan *et al.,* 2021).

In low-income sub-Saharan African countries, the Ghana is typical facing significant sanitation challenges. In Accra, about 200000 people consume raw vegetables or salad every day. The size of the risk group comprises on poor and children from all income classes where 95% lettuce consumed in the city (Amoah et al., 2007). In Pakistan, rapid wastewater discharges are growing particularly, in big cities which are mostly used to grow vegetables and fodders in the peri-urban areas (Ashraf et al., 2017). Pakistan's city Karachi's Korangi Drains wastewater including which industrial and sewage wastewater is used for vegetables production. Contaminated vegetables produced by wastewater irrigation and which has high level of heavy metals (Rabab et al., 2021).

Increasing water scarcity and droughts as long with lack of suitable and sufficient setups for purifying the water which are ways of contamination in clean water resources of irrigation (Rutkowski et al., 2007). In many parts of the world wastewater irrigation in case of water scarcity supports the agricultural production and improve the living of millions of small land holder farmers (Sato et al., 2013) furthermore, this type of irrigation system decreases the quantity of irrigation water that needs to be supplied so it can be suggested for wastewater reuse in irrigation (Libutti et al., 2018).

Wastewater reuse is not only providing substantial quantity of irrigation water, but also contributes to save potable water resources and decreases the environmental impact associated to the sewages released into the rivers and lakes (Agrafioti and Diamadopoulos, 2012). Raw sewage is generally used for agriculture in developing countries to fulfill the water stress. Even though it is a good source of nutrients for plants and crops, such wastewater also rises the load of heavy metals to soils, which also has its impacts on the food chain. The untreated wastewater is being used to irrigate about 32,500 ha of land in Pakistan (Murtaza et al., 2010; Enisk et al., 2004).

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Long-term irrigation with polluted water of river has resulted in accumulation of various heavy metals in the soil (Liang et al., 2014). The human and fecal pathogens and heavy metals present in the wastewater-irrigated soils (Zia et al., 2017).

Wastewater irrigation has significantly increased the total metal concentration in wastewater irrigated soil (Jan et al., 2010). In developing countries, mostly farmers are using wastewater for irrigation and very few are using health safety precautions for human, animal and environmental health and very less are concerned to improve the valuable use of nutrients and water (Martijn and Redwood, 2015).

1.1 Objectives

1. The find out the key features of the previous studies about this topic.
2. To assess the farmers perception of wastewater irrigation by literature.
3. The current gap in knowledge, next challenges and suggestions to be approached.

2. Methodology

This study assembled the peer-reviewed journal papers including conference proceedings and book chapters that posits wastewater irrigation. Keywords which were used to obtain information on farmers' perceptions and factors affecting wastewater usage were combined as follows: ((socio-cultural aspects, wastewater, perception) AND (farmers' perception and wastewater, irrigation) AND (farmers, attitude, treated wastewater) AND (wastewater use, health externalities) AND (irrigation water scarcity, water users' association) AND (wastewater reuse. Socio-economic-agriculture) AND (farmer, wastewater) AND (farmer's perception, vegetable production, wastewater irrigation) AND (public perceptions, behavior analysis, agriculture water management) AND (treated wastewater) AND (farmers' attitude, emerging contaminants)). Various databases were used to search the research papers. The particular readings included above-mentioned keywords in their abstracts or titles or in keywords. A total number of 76 including research papers, book chapters and org. reports were gathered, which were published since 2000 and most recently in 2022. Farmers' perceptions were most investigated as well as the factors affecting wastewater usage and its health impacts.

3. Key features of reviewed papers

Yearly distribution of reviewed literature on the base of its characteristics such as number of papers, geographical context, key words, qualitative and quantitative tools as well as data analysis methods.

3 Results and Discussion

3.1 Use of wastewater in agriculture

Farmers generally view wastewater negatively and have good information about quality of wastewater and its adverse effects on health. Farmers like to use wastewater for irrigation because it has economic sustainability. The economic worth of wastewater irrigation is, it is cheap source of irrigation with no or lowest cost on crop production (Singh et al., 2021).

In a study of Italy, the farmers had noticeable perception of benefits rather than risks from wastewater reuse in agriculture (Michetti et al., 2019) In Faisalabad Pakistan, growers have good information of the fertility values of wastewater (Sohail et al., 2021). In Greece farmers are willing to pay (WTP) for treated recycled wastewater and consumers are willing to use (WTU) the recycled water and products produce by it. This showed their concerned behavior towards health impacts of wastewater irrigation (Menegaki et al., 2007).

However, in the Jordan Valley the understanding adjacent to wastewater reuse for vegetables and fruits in agriculture possible contributes to adverse opinion (Carr et al., 2011). Wastewater using farmers have comparatively less information of its negative effects

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on health as related to their counter parts who are using freshwater (Mehmood et al., 2022). The farmers in another area are conscious of wastewater's negative impacts on health of humans and soil. Due to high temperature and impurities, only a limited number of farmers are using wastewater for irrigation of sugarcane and rice by thinning it during the insufficiency of freshwater. The term 'wastewater' denotes to 'untreated sewage water'. Farmers like to use wastewater due to its fertility, reliability and low cost of wastewater in one level, and observed, as harmful elements, the presence of solid wastes, fecal matter, engine oil, grease, diesel, molasses, and harmful chemicals in the other extent (Mojid et al., 2010).

Farmers had comparatively high information about unsuitable value of raw wastewater and its adverse effects. While growers are anxious about the human health, social impacts and environmental impacts of raw wastewater (Pratap et al., 2021)

3.2 Factors behind the usage of wastewater irrigation

In slum areas of Chandigarh, farmers prefer to use wastewater for agriculture irrigation due to its economically beneficial property (Singh et al., 2021). Knowledge and attitude of farmers are most predominant factors that effects the degree of adoption of untreated wastewater (Lahlou et al., 2021).

In developing countries many farmers are facing water scarcity and wastewater at that place is the only source of irrigation water that's why they are focused to use it for irrigation. On the other side its use decreases the necessity for buying fertilizer, lessen the energy cost and it allows farmers to harvest high worth vegetables for sale in hometown markets (Sato et al., 2013).

Cultural and socio-economic aspects of the rural population are the main factors linked with reclaim wastewater irrigation in agriculture (Nawaz et al., 2022). Using wastewater resource is economically profitable (Maleksaeidi et al., 2018). For agriculture purpose, renewable and valuable source of irrigation is wastewater (Nassar and Al-najar, 2009) it is economically improvement for farmers a chance for profits (Ensik et al., 2002).

Wastewater irrigation involves a huge number of farming laborers (Pratap et al., 2021). In developing countries, mixing of exhausted water due to poor infrastructure have produced condition in which growers go to raw wastewater as a substitute source of water for irrigation (Rutkowski et al., 2007). Important reasons to prefer wastewater for irrigation is, it is beneficial source to avoid high cost of propelling groundwater and to save on fertilizers. Also, farmers get good yield by using wastewater (Mojid et al., 2010).

In consumers major factors affecting the purchase of vegetables are; taste, freshness of produce, cost, convenience and friendship with vendor (Antwi-agyei et al., 2016). Farmers preferred to use wastewater to fulfill the need of freshwater in water scarcity areas and factors affecting to use wastewater due to wastewater's availability nearby the farms, high production of crops, nourishes soil and deliberate basis of nutrients for plants (Ndunda and Mungatana, 2013).

In Kumasi of Ghana, socio-economic characteristics of farmers such as gender, education and age and perceptions of farmers on health risks due to raw wastewater irrigation are major factors behind the use of wastewater irrigation (Owusu et al., 2012). On the island of Crete, Greece the shortage of fresh water resources is a main cause of using wastewater by farmers (Menegaki et al., 2007). Water shortage and declined cost of production are the key reasons behind the use wastewater for vegetable cultivation and production (Mehmood et al., 2022).

In developing countries, rising populations, urbanization, and industrialization are main factors to increase the production of wastewater and various challenges such as

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ISSN P: 3006-1458
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drought, water scarcity, and inappropriate infrastructure for refining wastewater are pushing factors to many farmers to reuse raw wastewater as another source of water instead of freshwater for irrigation (Strokal et al., 2021).Wastewater offers better livelihood to numerous poor residents of urban areas and it is a basis of inexpensive and fresh produce (Ensink et al., 2007). Farmers like wastewater irrigation instead of freshwater irrigation because it is cost free, easy to access and healthy for crops that are giving good return (Tripathi and Chintamanie, 2010). Farmers in Pakistan, consider wastewater due to its high productivity and profitability they considered it a valuable source of irrigation (Ensik et al., 2002). In Jordan religion act as a factor affecting on perception of wastewater or reclaimed water usage (Carr et al., 2011). Culture is another main factor behind the usage of wastewater irrigation as it affects the decision-making processes and attitude change (Ricart et al., 2019).

3.3 Health-risks due to wastewater irrigation

In a study of Morocco, wastewater irrigation caused heavy metals accumulation in plants and crops which is a serious threat for crops, soil and for human health (Chaoua et al., 2019). Although, untreated wastewater irrigation poses serious health risks (Ensink et al., 2005). In Mingora Swat Pakistan, adults had more exposure to wastewater as compared to children therefore total HI in adults is more than children and in the reasons behind it is, prolonged consumption of wastewater irrigated vegetables in adults as compared to the children (Ullah et al., 2022). Raw vegetables mostly unwashed are more likely a way of transmission of abdominal parasites to human body (Fallah et al., 2012). Wastewater has protozoa, viruses, and bacteria and they can spread sicknesses like hepatitis A, cholera, salmonellosis, diarrhea, giardiasis, shigellosis, and other viral enteritis (WHO, 2006).

Wastewater use in agriculture is very risky and its risks are wide, ranging from changes to microbiological and physicochemical properties of soils to influence the health of humans (Jaramillo and Restrepo, 2017). Vegetables cultivation at polluted sites in Sahre-Rey could accumulate metals in high concentrations that are probably toxic to human health (Bigdeli and Seilsepour, 2008). Enduring wastewater irrigation is replete with numerous significantly known concerns about steady deposition of toxic metals in agricultural soil and food crops which make consumers vulnerable to experience the contaminants and pathogens (Nabulo et al. 2010; Qureshi et al. 2016).

Due to wastewater irrigation in Marrakech, highly toxic metals such as zinc, copper, lead and cadmium are accumulated in water, irrigated land and agriculture crops and has their worsen impact on health of humans (Chaoua et al., 2019). Sewage and industrial wastewater of Faisalabad Pakistan, has higher values than Pakistan Environment Quality Standards (PEQs) and its shocking situation for consumers' health and environment (Sohail et al., 2021).

Wastewater contains heavy metals such as mercury and cadmium which exert its negative effects and positive nutrients values fails in compare with its negative adverse effects of heavy metals (Mukherjee et al., 2013). Among the perceived health risks, skin problems are numerous among farmers (Woldetsadik et al., 2018).

However, the indirect and direct wastewater using farmers, face numerous risks of wastewater irrigation: such as, diarrheal diseases, unpleasant smell, worm infections, skin infection, blistering and damages the irrigation (Ndunda and Mungatana, 2013).

Health risks at farms like skin irritations considered as the major health risks which are generally linked with wastewater irrigation among farmers (Keraita et al., 2008). An increased risks of abdominal nematode worm infection and hookworm infection, specifically, wastewater using farmers and their families are most prominent (Ensink et al.,

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ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
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2005). Typically, the heavy metals mainly penetrated green vegetables as compared to other food crops and caused health problems (Adriano, 2001).

Gastroenteritis and chronic diarrheal diseases which excessively affects the urban slum residents who have improper sanitation and sewerage facilities, are undoubtedly major negative consequences of contact to wastewater (Scott and Faruqi, 2004).

Long-term use of wastewater could exaggerate the attentiveness of heavy metals in the water and soil, and decrease the soil quality, water and plant and also caused health risks to farmers and consumers (Khanpae et al., 2020). The Health Risk Index (HRI > 1) indicated that heavy metals presence in various vegetables had potential for consumers' health risk due to consumption of wastewater irrigated food crops and vegetables (Chaoua et al., 2019). Vegetable production using wastewater, specially, has tremendous negative externalities due to adverse effects on human health (Abedullah et al., 2011). Green vegetables have relatively high absorptions of heavy metals as compared to fruit vegetables (Bigdeli and Seilsepour, 2008).

Farmers of peri-urban and farming communities or residents living near to sugar mill faced the problems such as odd smell, skin infection (itching and blistering), injury to hands and legs, and damage to water lifting pumps during irrigation with wastewater. Growers at Chittagong stated an extra grievance of diarrhea because of contacting with wastewater (Mojid et al., 2010).

As total annual economic value of labor productivity loss due to different sicknesses is estimated to be around Rs.33.50 million and after internalizing the externality costs (Abedullah et al., 2011). The uptake of heavy metals in excessive quantity in crops is route to cause serious health related problems (Chen and Wang, 2005). Wastewater in untreated form cause lead accumulation in soil and its transformation in eatable parts of the vegetables. Vegetables contaminated by lead, and as such Pb-induced human health risks in farmers and consumers (Khalid et al., 2017).

Growers seldom use protecting dress or rarely do any protecting measures when applying water or sprays in wastewater irrigated fields. Very few farmers have knowledge of protective measures during handling wastewater irrigation but cannot afford them or give them slight importance (Keraita et al., 2002). The most of wastewater irrigated farmers and their families are prone to stomach disorders and intestinal parasites (Tripathi and Chintamanie, 2010). Wastewater might have a diversity of contaminants, such as viruses, salts, organic compounds, heavy metals, and enteric bacteria. An extreme accretion of trace metals in soil through wastewater irrigation cause difficulties for agricultural production (Singh et al., 2004).

Through the heavy metals up take with the contaminated food caused numerous health problems such as; intra-uterine growth obstruction, impaired psycho-social behavior disabilities linked to undernourishment as well as cancer in gastrointestinal (Arora et al., 2008) untreated wastewater generally has high levels of pathogens that could be spread by direct contact to growers and also to the public by consuming wastewater irrigated produce, especially raw vegetables (Blumenthal et al., 2000; Keraita et al. ,2003). The key problem linked with wastewater irrigation is the entrance of pathogens in the food. They are associated with serious health dangers to growers and consumers (Petterson et al. 2001; Toze 2006; Rubino and Lonigro 2008)

3.4 Exposure pathway to health-risks

Direct consumption of food irrigated by wastewater is one of the exposure pathways of pathogenic microorganisms. Helminth diseases are most prominent in farmers because farmers have direct exposure with wastewater and wastewater irrigated soil (Woldetsadik

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
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et al., 2018). Unclean post-harvest management of vegetables is the main cause of food infection (Ensink et al., 2007). In urban inhabitants, usually the raw vegetables consumption is a primary exposure route that have been irrigated with wastewater (Scott and Faruqui, 2004). Heavy metals contact due to wastewater irrigated food ingestion is dangerous for human health (Sanaei et al., 2021).

Metals transferred to humans and destroy their health because of the consumption of polluted vegetables (Chen and wang, 2005). Lettuce which is green vegetable is got contaminated at cultivation farm sites instead of post-harvest sites (Amoah et al., 2007). There are numerous assistances as well as risks linked with sewer water irrigation (Pratap et al., 2021).

Suggestions and Discussion based on review.

Technical and social issues must be addressed on the use of domestic water (Ricart et al., 2019). Harmful effects of wastewater can be minimized through recycling of wastewater with the help of new treatment technologies (Qadir et al., 2010). Use of treated wastewater in crops production is common activity and it may help to confirm safe and sustainable food crops (Pedrero et al., 2010). The reuse of untreated wastewater in crops irrigation not only rises farmers' health expenses but also due to illness cause a harm in income and productivity as well as environmental negative impacts like land degradation (Alnaimy et al., 2021). Wastewater irrigation may be a source to depletion of pollution into groundwater resources (Jampani et al., 2020).

Conjunctive use of both treated wastewater and ground water is best way for water reuse in agriculture and lessen economic pressure on community (Mahjoub et al., 2022). Non-traditional wastewater such as treated wastewater is the best way to solve the scarcity of water for agriculture. The uncontrolled long-term use of wastewater has many disapproving impacts on crops and soil. It also decreases the requirement to supply exclusive chemical fertilizers to the soil. It decreases the contamination of crops and lessens risks to human health by minimizing the physical contact of wastewater and farmers and crops (Hashem and Qi, 2021).

Interventions at the market, such as the facility of clean water to wash vegetables in, are good ways to protect the public health and it is good and very cost effective than treatment of wastewater (Ensink et al., 2007). The use of ordinary washing procedure before consumption of vegetables as a replacement for traditional ways (Fallah et al., 2012) Also, education is essential to increase knowledge of farmers about water resources and expand their attention and moral responsibilities to the public health (Maleksaeidi et al., 2018).

Key to the success of actions to make the changes in planned reuse programs are a clear authorized and institutional framework with formal mechanisms to harmonize the actions of multiple government authorities and charges of payment should apply to people who pollute the water, adaptation of growers towards more suitable practices for wastewater use, public awareness campaigns to launch social acceptability for reuse, and reliable government and civil society assurance over the long term with the understanding that there are no instant solutions (Scott et al., 2004).

Government or policy makers should introduce new strategies for recycled wastewater. To make it more popular it is mandatory to deliver fresh water to people in higher economic prices. Afterward, it will be a good way to pay for the treated wastewater which would be cheap in price as compared to freshwater resources. The attitude of "pay-because-you-don't use recycled water in cases where you could" in a fashion corresponding to the "pay-as-you pollute" belief, if merged into the price of fresh water, will initiate

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ISSN P: 3006-1458
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additional people to use treated wastewater as an alternate of fresh water, even for household use. Consumers get extra discounts on crops produced by treated wastewater (Menegaki et al., 2007).

Water irrigation method is old fashioned which caused more water loss and to overcome the issue of increasing water scarcity is to adopt the water-saving technologies in irrigation (Juvariya et al., 2022). Farmers who have knowledge of health risks of wastewater irrigation and their awareness doesn't affect the adoption of safer farm practices furthermore, consumers while purchasing the vegetables from vegetables' vendors did not prioritize health indicators (Antwi-agyei et al., 2016). Wastewater authorities must improve as well as sharing of charges and obligations among farmers, wastewater producers and government institutions can increase nutrient recycling, water use efficacy and crop production while defending environment and public health. This requires economic, financial and social inducements in developing countries to minimize the risks along the exposure pathways from growers to vendors and to consumers (Hanjra et al., 2012).

The recycled wastewater irrigation will expose an improvement of groundwater pressure, dropping on about 49% water abstractions and it will decrease dependency on groundwater pumping (Ramirez et al., 2021).

The education about the use of extra procedures that effect pathogen die-off such as sunlight intensity, temperature and crop type should promote that can help in lessening the pathogen load in irrigation water (Silverman et al. 2014). The use of sedimentation ponds, slow sand filtration systems that are considered ideal in treating irrigation water in which sand filters remove pathogens from contaminated water should promote at local level (Stevik et al., 2004). It is crucial for health education to improve the awareness level of vendors about hygiene and food safety. Vendors need to be aware of hygienic, sanitary and technological features of street food vending and consumption (Ackah et al., 2011).

Conflict of Interest

Authors have no conflicts of interests.

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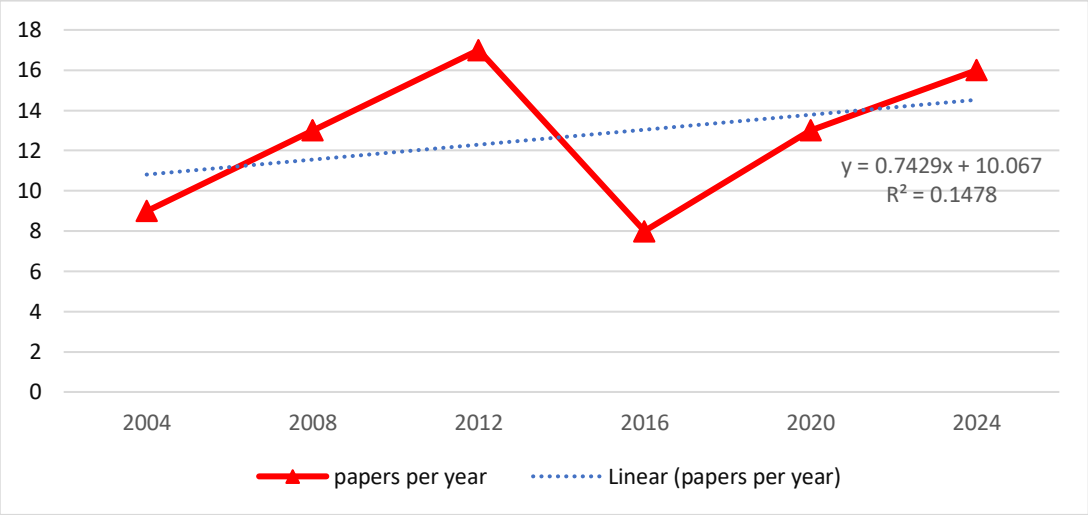
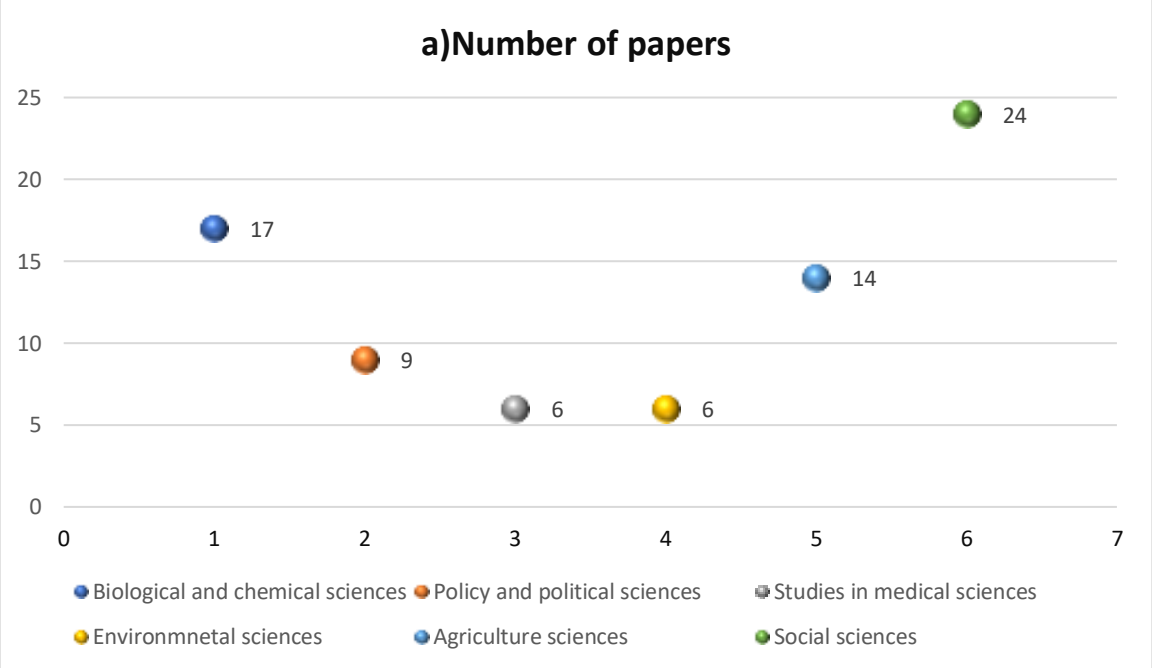


Fig.1. Yearly distribution of selected papers.



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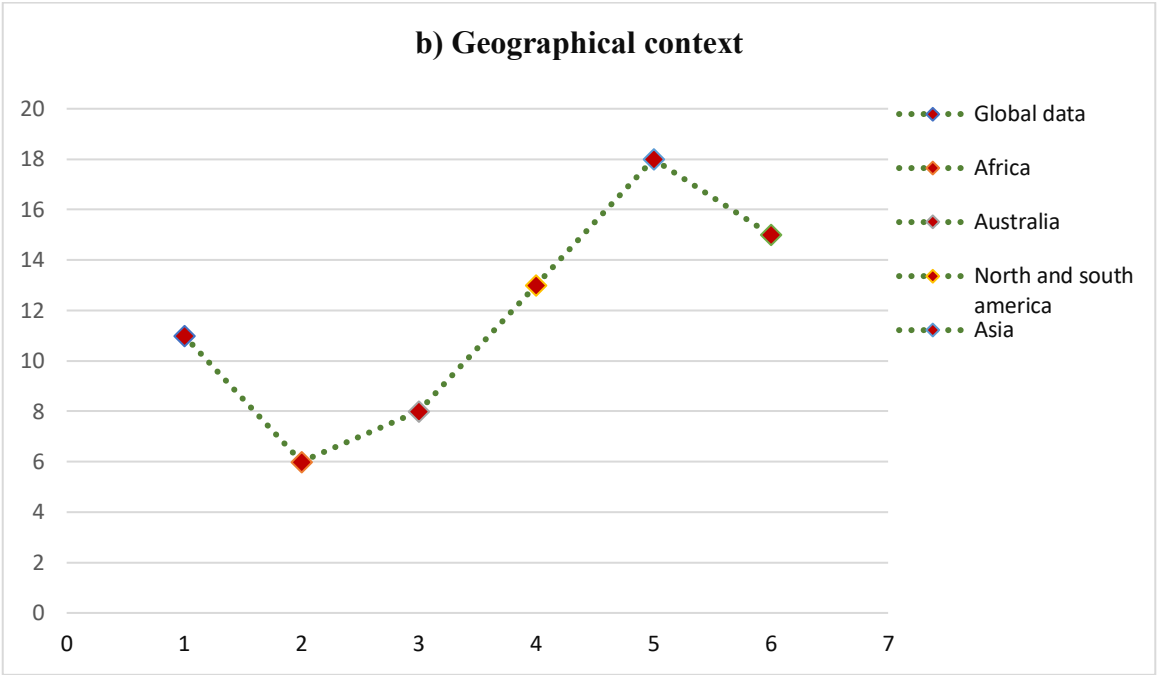
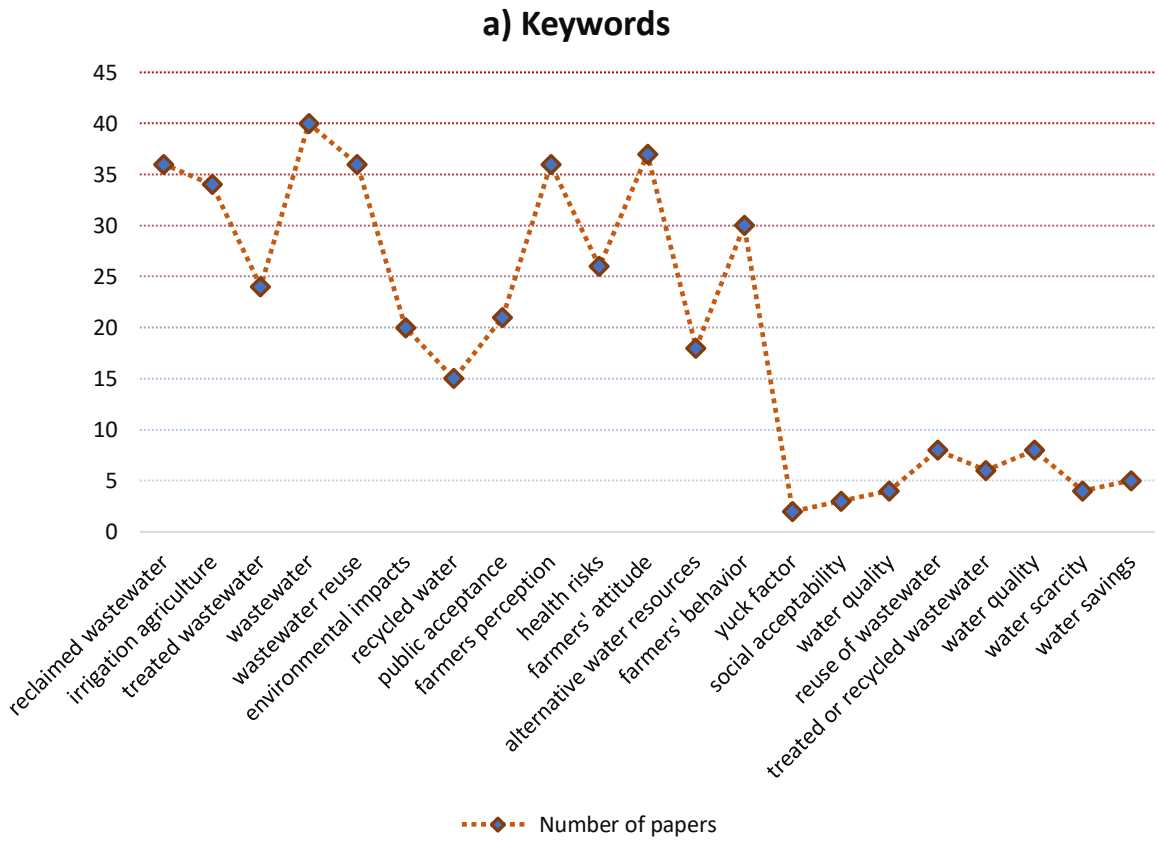
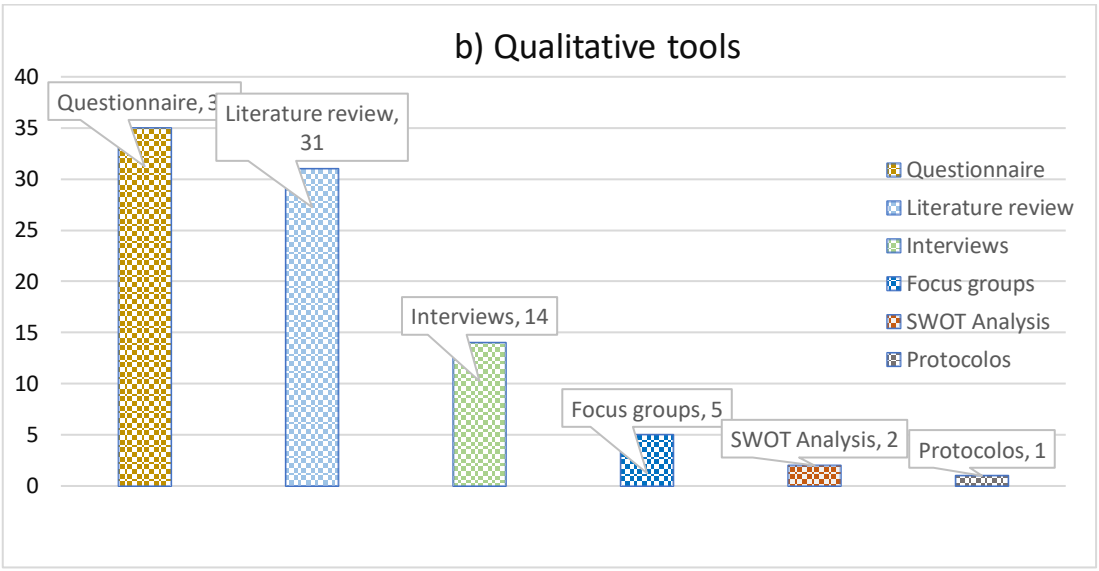


Fig. 2. Geographical context and research areas of selected papers



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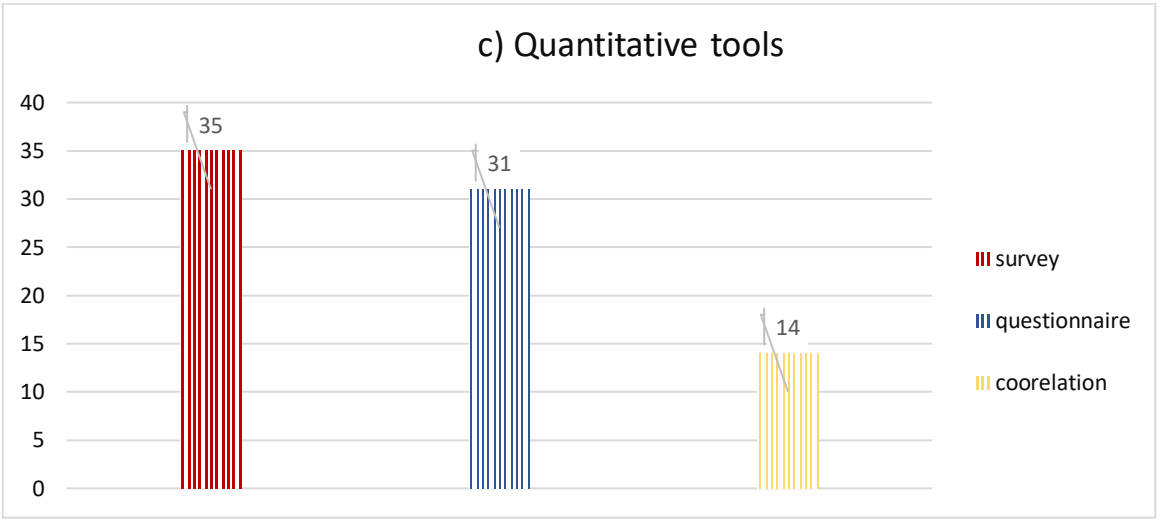


Fig. 3. Key words and research designs (qualitative & quantitative) of selected papers

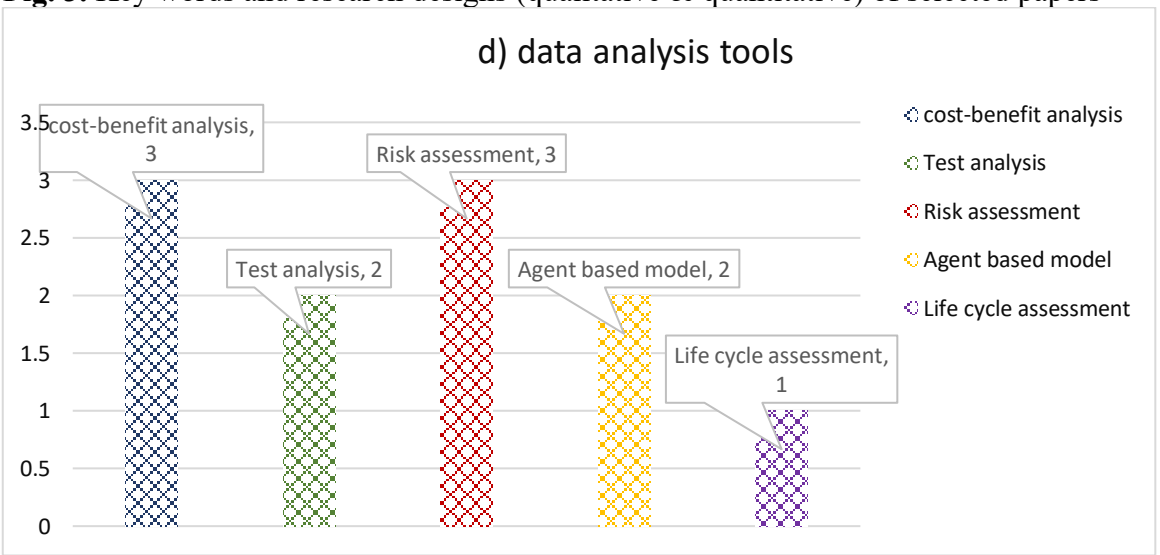


Fig. 4. Tools used for data analysis in selected papers.