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Estimating The Effects Of Flash Floods On Agriculture Using Depth Damage Curves

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ABSTRACT

Pakistan is being regularly hit by different types of floods among them the flash floods cause devastation to both the lives and properties of people. This study is designed to assess the flash flood damage to the agriculture sector in the Watalai khwar flood plain. A mix of both primary and secondary data collection techniques are used. The most affected villages are ranked and five are selected based on the proximity with the main channel for the detailed data collection. The collected data is analyzed to produce depth damage curves, highlighting the extent of damage to agriculture at different water levels. The study finds that a significant area of agriculture particularly adjacent to the main water channel is vulnerable to varying intensities of flash floods. The regression analysis highlights a positive correlation between the flash flood water depth and the damage it cause to agriculture in the study area. Effective flood risk management strategies and policies are essential to be formulated for the agriculture sector in the area. The authorities must devise ways and means for the prevention of encroachment towards the main water channel. Moreover both structural and non structural mitigation measures need to be taken for the better flood risk management in the area. To prepare the community to cope with flash floods a comprehensive early warning system is also needed to be installed.

Keywords: Damage,Watalai, Flashflood, Agriculture Crops.

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Introduction

Flood is the most frequently occurring disasters that cause damage to the lives, property and the natural environment. According to Sendai framework 2015-2030 the climate change and the rapid urbanization are major causes of the increased devastating flood events (Teitelbaum, et al. 1991).Among all the segments of the economy agriculture sector stands out the most vulnerable sector to various disasters, an estimate shows that around 26% of the global impacts of disasters are absorbed by agriculture sector(FAO,2021). Droughts and floods are the most common disasters affecting the agriculture sectorinthedevelopingcountries.FAO,2015estimatedthat34%ofthelossto agriculture is attributed to droughts, while flood damage around 19% of the agriculture. Agriculture is the main segment of economy in many of the Asian countries thus when a flood occurs it significantly affect the agriculturesector.TheagriculturesectorinPakistanplaysanimportantroleitcontrib utesaround 22.9 percent in the country's GDP and generates 37.4 percent of the total employment of the country. It also ensures the food security and the provision of raw material to the industrial sector. Moreover it acts as a significant source of foreign exchange earnings. However in Pakistan due to climatic shocks the country's agriculture sector is adversely affected specially in the last couple of decades. As the agriculture productivity is highly sensitivity to the rains and heat waves.

During the months of July and August 2022, unprecedented an estimated 10 times more rainfall has caused heavy floods in almost all parts of Pakistan.It killed around 1100 people and displaced some 33 million people throughout the country. Furthermore billions of dollars of damage to the residential, commercial and agriculture sector has also occurred. a loss to the economy of the country as a result of the event is 15.2 billion. To recover from the eventan additional 16.3 billion is required. Residential is the most affected sector of the economy which suffered 5.6 billion US$, followed by agriculture with a total loss of 3.7 billion US$ to the sector. This has had negative consequences on the food industry, which increased the overall price of foodstuff. Overall the economy of the country has suffered severely as a result of the event. The country's prime minister has resulted in damage that would require additional 10 billion to recover from the event (European Space Agency, 2022).

Historically the Watalai khwar which has been selected for the study has witnessed a numbers of flash floods, for instance the flash flood events of the year 1973, 1992, 2000, 2010, 2012, 2017 and 2018 are the most dreadful of all. These flash floods have brought havoc resulting in loss of lives and caused significant damage to the residential, commercial, and agriculture sectors(FDMA, 2012; HUJRA, 2015; NEWS International, 2018). Recently in the year 2019 flash flood triggered by heavy rainfall in different parts of the study area caused major loss to wheat crops and damaged infrastructure and other properties (NEWS International, 2018).

Flood damage assessment is mainly focused on the residential, commercial and industrial however agriculture sector being major source of production of industry is given less attention (Merz et al 2010). Therefore a comprehensive damage assessment for agriculture sector is required to estimate the damage to agriculture due to flash flood. Flood inundation parameters are very much important to be considered while developing a methodology to assess the agriculture flash flood damage. These indicators include water depth level, flood duration, flood water velocity, soil type, land use (Merz et al., 2004). Pivote et al., 2002 also include crop species or variety, crop growth phase during flooding and debris transport to be included in the flash flood damage assessment. Shresta et al., (2018), describe the methods for estimation of flood damages to the agriculture sector. They analyses the case studies of flood damages assessment that are conducted in different regions of Asian river basins. The assessment is conducted based on depth, duration and growth stage of the crops by employing depth duration damages function for every growth stage of crops. The methodology is validated by comparing the calculated data with the reported data thus matches each other.

Flood water depth is the key parameter considered in many studies related to the estimation of agriculture flash flood damage (Dutta et al., 2002; Thieken et al., 2008). Such assessment is called depth damage function. The construction of Depth damage function is mainly carried out byemploying historic flood damage data or it is derived synthetically by consulting experts in the field. Usually historic data is not available therefore researchers mainly undergo synthetic damage assessment (Merz et al., 2010) (Smith, 1994).The results of Depth damage functions are then shown in the form of depth damage curves. The current study also considers flash flood water depth as the main indicator of the damage to the agriculture sector. The main objectives of the study are to evaluate the potential flash flood damage to the agriculture fields and crops and to forward recommendation to the policy makers for informed decision making on flash flood risk management.

Literature Review

The literature review aims at the identification of key flood impacts on different sectors of the society, its economic implications and the methods of evaluating flood damage in different part of the world.

Flood Damage

Flood is the most frequently occurring disasters which causes widespread damages and ruin more fertile land than any other disasters do. For instance floods have caused about a third of overall 630 billion US$ loses in the world during the time span between 1986 and 1995. It is further estimated that about three quarters of the total 7000 disaster that have occurred are water related of which flood is the most destructive one (Dutta, 2003; Munich-Re, 1997). Natural hazards killed 367000 people throughout the world in ten years i.e. 1986-1995 an estimated fifty percent of the victims are related to floods of all types (Munich-Re, 1997).

Floods have diverse impacts on a society it may cause death or injury of people, may damage buildings or disturb the production of goods and services (Merz, 2006). Messner& Meyer (2006) simply defined damages from floods as all varieties of harm caused by floods. For example the harmful effects on man and its properties, and other negative type of impacts on life support services and agricultural and industrial yields (Messner& Meyer, 2006; Merz et al. 2010). Friedland (2009) defined flood damages as the direct consequences of a flood are the attributes that can be measured in term of any level of destruction, spoil or degradation is called flood damages. It is equal to the amount of money required to restore the affected area to its pre flood conditions (Grigg&Helweg, 1974). Damages from flood can be classified as direct and indirect (Bubeck, 2008).

Direct damage

Those damages which are caused as a result of direct contact with the flood water it include damages to property or loss of lives or injuries. Such types of damage always occur in the area directly affected by the flood (Merz et al., 2010).

Damages to residential sector always occur to the building fabrics and other properties. In household case mostly the value of building is more than the value of the contents. All the damages both to building and contents in residential sector are placed in the category of direct damage (Thieken et al., 2005). Commercial direct damages include the damages to commercial building its furnishing and the stock it has. It also includes the cleanup cost of the commercial property after the flood is over. All the production of industrial sector may also halt as a result of the flood water inundation. The cost of damages is highly dependent on the type of business sector it involved in (Gissing &Blong, 2004). Flood water also affects the public utilities which include the transmission line, sewers lines and water supply pipes. In general the disturbance of electric and gas transmission lines costs more during a flood (White, 1945).

Direct flood damage to agriculture includes the loss to fully grown crops, stored crops, grown orchards, livestock and its stored food, equipment and tools related to agriculture, farm houses, fences and irrigation channels. The overflow of water which brings sand and debris over the land damages the production. Also reduced future agriculture production due to flood is counted in direct damages (Lekuthai & Vongvisessomjai, 2001; Messner & Meyer, 2006).

Indirect damages

Damages which is caused not as a result of direct contact with the flood water but are mainly because of troubling the economic supply lines. This results in loss of production of goods and services. The rerouting of essential services due to disruption of roads may also be costlier hence contributes in price hike (Lekuthai & Vongvisessomjai 2001; Messner& Meyer, 2006; Merz et al., 2010). Indirect damages may be physiological, chronological, social, ecological or environmental and may happen during or after a flood event (Merz et al., 2004). Flash floods sometime effect an area greater than those actually flooded (Smith and ward, 1998). The severity of flood event determines the indirect losses and may be correlated with the direct damages. Indirect damages usually occur outside the flooding regions. The overall duration of the flood is a key factor of measuring the indirect losses specially the manufacturing and transporting disruption (Parker et al., 1987; Smith & Ward, 1998). Other indirect costs like the cost of damages avoiding activities and the provision of emergency services are also considerable(Penning& Wilson, 2006).

There are certain damages which are borne by the flood victims like extra transport costs but can't be quantifying with accuracy. Such as Increased living expense may also be included in indirect costs (Messner, 2007).

Flood Damages Assessment

Damages assessment is an important process of today's disaster relief and recovery. It is quite imposable to mobilize any significant response without analyzing the impacts of a disaster (Jha et al. 2010). Damage assessment is carried out to know about the extent of loss that the elements at risk suffer as a result of the occurrence of a disaster. The elements at risk include the structure type of the buildings, the contents of the building and the outside properties (Sagala, 2006).Duta et al. (2005) stated that flood damages assessment is important for reconstruction and recovery after a flood event. Hence, it is important to design prevention and mitigation activities based on damages assessment to prevent damages from future flooding.

Meyer and Messner (2005) investigated the different methodologies of flood damages evaluation in the Europe Union. They concluded that all the approaches used the idea of assignment of economic values to the damages categories. Lea et al. (2017) conducted a literature review of the damages assessment approaches that exist in Australia, Unite Kingdom, Germany and Denmark. They concluded that a wide variety of methods exists that are distinguished from one another in the level of details applied and the damages categories considered. Penning-Rowsell& Chatterton (1977) produced an all-time best manual which serves as one of the best procedures for assessing residential, agricultural, commercial and industrial damages.

Flood damage can be assessed either financially or economically. The financial damages evaluation looks at damages from a prospective of a single person or firm, thus totally neglecting public affairs and focusing on actual financial burden. While economic damages evaluation has a broader perspective and wants to assess the impact on intangible goods and services e.g. one person loss can be another person's gain (Merz etal., 2010).Flood damages assessment is of great interest to the insurance companies however due to business purpose restriction they are reluctant to publish it. So these insurance companies have little contribution in developing any methodology for damages assessment (Van der Sande, 2001).

Damages assessment is performed in different spatial scales Micro-scale, Meso-Scale and Macro-scale. In Micro-scale assessment damages assessment is done based on single element at risk. Meso-Scale is such type of assessment in which assessment is done on aggregation of Land Use Land Cover units. The aggregated units are agriculture, industrial and commercial sectors etc. Macro-scale assessment is usually done for large scale area such as administrative unit like municipality, region and countries etc. (Merz, et al. 2010).

Flood damage assessment can be quantitatively done by analyzing the hazard, exposure and the vulnerability. Many studies show that a number of methods for the flood damage assessment are available (Penning-Rowsell & Chatterton 1977; Antonie et al. 1997; Smith and ward 1998;Aglan et al., 2004). However experts have mainly used two methods for the assessments of flash flood damages these include Depth damage curve and Multi criteria decision making tool(Sinha et al. 2008; Myer et al. 2009; Merz, 2010).

Multi-criteria analysis is a decision making tool which is used to solve very complex problems to give desired results. It is an umbrella term used to describe a set of methods and techniques for structuring and evaluating alternatives on the basis of multiple criteria and objectives (Voogd, 1983).These methods provide targeted decisions, as they can handle the inherent complexity and uncertainty of such problems as well as the knowledge arising from the participation of several actors (Yan et al., 2011; Zagonari and Rossi, 2013).

In flash flood damages assessment Multi Criteria Decision making Analysis (MCDMA) can be used to know about the significance of different Land Use Land Cover types and thus to indicate the overall severity of the damages caused by flood (Saaty, 1980). Multi criteria decision making tool was used by Chen et al. (2011) for the assessment of flood risk in Taiwan. Sinha et al. (2008) assessed flood damages in Bihar India they used Analytical Hierarchy Process to identify flood intensifying factors. His study only proposed areas that would come under water of a specific intensity. However, its limitation is that it only shows the areas that would be inundated without mentioning of the monetary loss (Chen et al., 2016).

The second appropriate method of assessing flood damages is the Depth Damage Curves. It was used by White (1945 and 1964) for the fiRst time. It is the most widely used numerical method used for flood damages estimation (Meyer et al., 2007; Tang et al., 1992;Freni et al., 2010). A depth damage curve shows the relationship between the depth of inundation and the damages expected. Depth damage curves require information related to the building value, depth of floodwater and velocity of water flow to estimate building damages (Chen et al., 2016). Two approaches namely empirical and synthetic may be used to construct depth damage curves (Green et al., 1994; Dutta et al., 2003), which will be discussed as follows:

2.8.1.Empirical approach

The empirical approach is based on data collected from an observed flood. Thus depth damage curve is built from the already existing data. Such type of data is usually collected after a flood event. Mainly researchers dealing with loss adjustment and quantity surveyors carry out surveys after a flood event and record the damages in all sectors of a community. Thus a real flood damages picture is portrayed. Some pertaining issues affect such types of data, the respondents usually exaggerate the damages because they expect for any sort of compensation. The second thing is that at the early stage when a flood is over it is quite difficult to estimate the actual damages it causes to any sector of a society (Messner et al., 2007).

2.8.2.Synthetic flood damages data

This method does not rely on the availability of actual flood data rather a flood like scenario is created. It actually relies on data which is generated through “what if” type questions (White 1945; 1964). It is based on expert judgment in which data regarding damages is collected. Such method is used in areas where no recent data regarding flood is available. The buildings in the flood prone areas are visited physically and the structures as well as contents are recorded for damages of any specific intensity of flood event or the damages are estimated through well trained loss adjuster. For instance Penning Rowsell and chatterton (1977) published synthetic damages data in the UK similarly Parker et al. (1987) presented a depth damage curves for different categories for Japan. In the real world case data is not always available easily therefore a synthetic model is mostly widely used.

2.8.3. Unit area approach

The unit loss model was actually developed by the American scientists White (1945) and was adopted later on by the Australian and Britain flood researchers (Parker and Penning-Rowsell, 1972; Smith & Greenway, 1988). This is widely used for residential, commercial and industrial where size of the plot/area is taken for estimating of damages. It is actually the individual type of damages per unit of the area of the floor space of a property (Penning-Rowsell et al., 1987; Tang et al., 1992).

2.8.4. Relative approach

This approach is commonly used in the European countries. It is usually applied to the market value of the building rather than the land and express flood damages potential as a percentage of that value. For example a damages of 65% is almost always considered as the major damages in which much of the building and its contents destroy completely similarly a 10% or less damages would consider as minor damages. This approach has its advantages as the data is always available on different sources and can be easily estimated to the potential damages.

Besides other factors this study is carrying out assessment of the monitory losses in the study area, therefore the method of synthetic depth damage curves was used for this study.

2.9. Steps of flood damages assessment

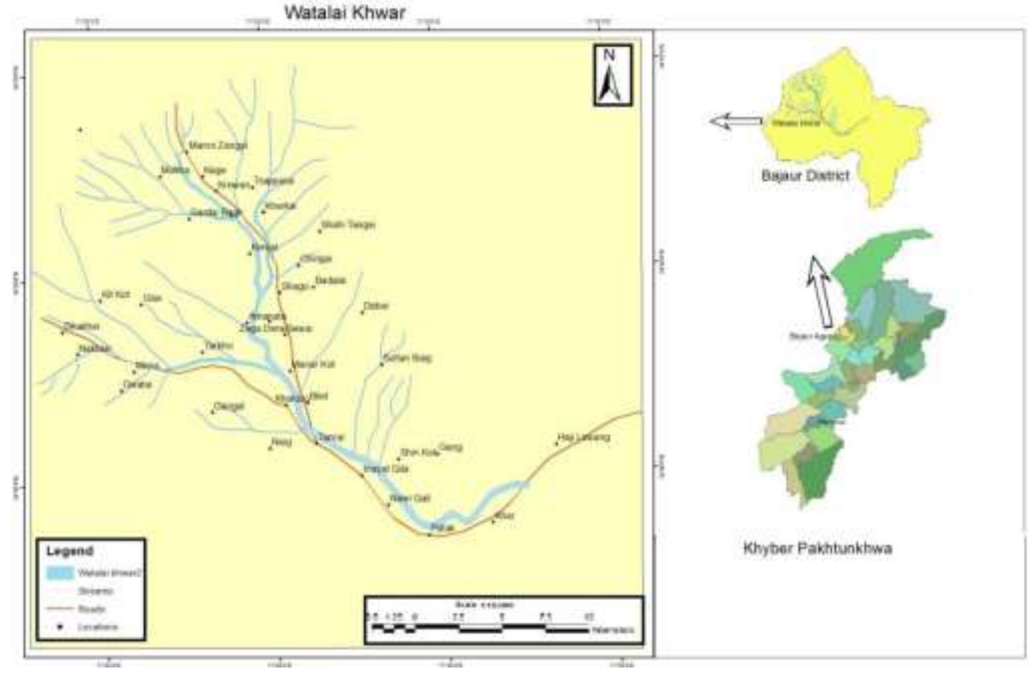
Depth damage curves is a step by step process of assessing damages caused due to flash floods. Literature shows that it involves the following five steps (Messner et al., 2007)

TheStudy Area

Thestudyareastretchingfrom˚30′to 34˚ 58′NorthLatitudesand71˚ 11'to71˚48'EastLongitudesissituatedindistrictBajaur,Khyber Pakhtunkhwa Pakistan (GOP, 1998). The climate of Bajaur is semi-arid, subtropical continental highland type. Historically the region receives around 800mm average precipitation predominantly during monsoon and spring seasons. Due to climate change a fluctuation in monsoon rainfall pattern in the study area is also observed in the past two decades. The upper mountainous region surrounding the district also gets its share of snow in the months of December and January. (GOP, 1998).

Watalai khwar originates from the high mountains of Mukha, KagaandKharkaiatanelevationof3040ftASLithasalengthofapproximately25 Km. The channel flow in north to south east direction where it joins the main Nawagai channel, collectively it falls in the Panjkora river district Dir. The total drainage area of the nullah is around 293 sq km containing both mountainous (210 sq km) and plan (183 sq km) regions. A number of narrow steep and dry tributaries mainly originate from the upper portion also contribute to the main Watalai water channel. Precipitation and snow fall in the upper mountainous region mainly feed the Watalai khwar (Fig. 1). Due to prolonged dry seasons the surface water in the channel dried up mainly in the middle portion however, surface water is still available in the lower and upper segments of the channel(USAID, 1991). According to the USAID, 1991 monsoon rains accompanied by the cloud burst in the upper mountainous region brings flash floods in the Watalai khwar.

Figure1.1Locationofthestudyarea.Source:1:50,000.SurveyofPakistanHEET 38N/5



3-Research Methodology

To achieve the desired objectives the study is carried out in four steps. In the first step information related flood hazard, crop types, annual yield are collected. Exposure and elements at risk are identified in the second step. During the third step values are assigned to agriculture crops damage of different types, in the last step all the data collected is analyzed and depth damage curves are developed.

Data Collection

Primary data from the field is collected via questionnaire, structural interviews and focus group discussions. General observations during data collection are also recorded. Sekaran 2003 table is used for the estimation of sample size around 310 questionnaires are prepared for the respondents in the most frequently affected villages. Proportionate sampling technique is used for deciding the number of respondents from each village. Moreover the participants are selected on the basis of random sampling techniques. Women also significantly contribute in the agriculture activitiestherefore10 percent of the respondents chosen for the study were women. Focus group discussions one each is held in five selected villages of the study area. The type of data collection includes the variety of crops growing and the damage caused at different height of flash flood water.

Different published and unpublished repots of the concerned governmental departments are considered for the collection of secondary data.Those include the PDMA Peshawar, Irrigation Department, the district administration and the agricultural extension department. Maps are derived from the image extracted from the SENTINEL II satellite. Aerial images are taken from the Google earth pro. District census report is consulted for the population and household data of the study area.

Data Analysis

An aerial image of the study area is extracted from the Google Earth to observe the agriculture activities. Based on previous flash floods some hypothetical water levels are assumed for evaluation of damage to agriculture in the study area. Furthermore the data obtained through questioners are analyzed with the help of software Excel-2016 and Statistical Package for Social sciences (SPSS) for the results. Descriptive statistics such as percentage is used to summarize and arrange the bulk of data. One way ANOVA is applied to compare the average damage with in each category. In order to investigate the relationship between dependent and independent variables regression analysis is performed. Similarly the data obtained via interviews, FGDs and observations are coded and summarized. Finally damage function for agriculture is presented.

Results and Discussions

The extension of agriculture fields lie on both side has narrowed the channel that cause the excess water during rainy season to overflow and affect the adjacent agriculture land causing damage to crops and the fields.Moreover the agricultureandbarrenlandsaredegradedasthetopfertilesoulerodeswiththe flowing flood water.

Fig.2. an Aerial view of the study area source Google Earth

Valuesareassignedtodifferentfieldsandcropstoestimatetheagriculture damage. The repair work to the damaged buildings is also assigned monetary values. White (1945) placed loss to stored crops, agriculture related buildings, equipment and the irrigation infrastructure in the category of direct damage to the agriculture sector as a result of flash flood. Additionally any future loss in production is also considered as direct damage to agriculture due to flash flood. Messner et al., 2007 highlights in their study that researchers place livestock with agriculture products in the damage assessment, however less detailed studies have excluded the livestock from the loss estimation.

The soil and atmospheric conditions of the study area are suitable for growing many crops for instance wheat, maize, and vegetables like tomato, peas and turnip etc. are the common crops growing in the area. Moreover different types of fruit orchards of are also grown in the study area (GOKP, 2021) Malik et al, 2023.Some of the famous fruits of the area include walnuts, plum, persimmon, apricot, and grapes etc. (GOP, 1998).Data from the field show that agriculture is one of the main sources of income of the people of the area. The table 1 provides a quantitative perspectiveontheagriculturesectoroftheareaitalsosummarizesthetypesof crops grown in the study area. Wheat and maize are the most growing crops in the study area. Around 54.84 Percent of the farmers grow maize and wheat crops.About31.62percentrespondentsoftheareaaregrowingvegetablesand around 08.06% and 05.48% of the farmers are growing orchards and fodders respectively.

Table3.1:Majorcropsgrowinginthestudyarea

CROPS	FREQUENCY	PERCENTAGE
MAIZE&WHEAT	170	**54.84**
VEGETABLES	98	**31.62**
ORCHARD	25	**08.06**
FODDER	17	**05.48**
OTHER	00	**00**
TOTAL	**310**	**100**

Source:Fieldsurvey,2021

According to the survey45.81% of the farmers are cultivating a land of up to 2 acrein size. Additionally, 26.77 percent of the respondents grow crops on a plot area ranging 3-5 acres. Likewise 14.19 and 10.33 percent of the farmer are involved in large scale farming cultivating an area of 6 to 8 acres and 9 to 10 acres. Similarly a little portion of the respondents also cultivate an area larger in size than 10 acres.

Table3.2:Area of cultivatedfields

Area of the field	Frequency	Percentage
1-2Acres	142	**45.81**
3-5Acres	83	**26.77**
6-8Acres	44	**14.19**
9-10Acres	32	**10.33**
Above10 Acres	09	**2.90**
Total	**310**	**100**

Source: Fieldsurvey,2021.

Due to its rural setup with limited economic opportunities in hand there sidents of the area are poor. They relyon agriculture and livestock as their main source of livelihoods. Generally the people of the area hold small land with only few exceptions (GOP, 1998).

Thetable3summarizesthedistributionofseasonalincomeduetocrop yield across different ranges. Survey shows, around 18.06% of the respondents' estimates that their crops yield around 50000 to 80000 pkr per season. Though this is the minimum range of income due to crop production still the percentage is quite notable. Furthermore The mid to high income categories ranges between 141000 to 180000 and 181000 to 250000 pkr have also some significant percentages i.e. 21.29% and 21.61% respectively. Similarly the highest percentages i.e. 21.95% lie in the income range above 251000 pkr. The soil of the study area is fertile and productive, and hence a considerable population has adopted agriculture as a mean of livelihood. This aligns with the study conducted by Bremond et al., (2013) who also noted that agriculture is the main source of production of countries in the continent of Asia.

Table3.3:Estimate productions of different agriculture fields

CROPSPRODUCTION(RS)	**FREQUENCY**	**PERCENTAGE**
50000-80000	56	**18.06**
81000-140000	53	**17.09**
141000-180000	67	**21.61**
181000-250000	66	**21.29**
251000 ABOVE	68	**21.95**
TOTAL	**310**	**100**

Source: Field survey,2021.

The study area is being regularly hit by flash flood as reported by FDMA (2012), HUJRA (2015),APP (2019). Data from the field also confirms this as majority of the respondents i.e. 95.81% reveals that flash floods of varying intensities impact their fields over time. In contrast a small number of the farmers i.e. 4.19%claim that their fields have never been affected by flash flood. This pattern of prevailing flash floods in the similar region is also highlighted by Ahmed et al. 2020 in the findings of their research study.

Table4:Effectsoffloodondifferent fields

FIELD(S)AFFECTED	FREQUENCY	PERCENTAGE
YES	297	**95.81**
NO	13	**04.19**
TOTAL	**310**	**100**

Source:Fieldsurvey,2021

About 59.81% of the sample population reported that flash floods of different magnitude affect their fields twice a year. Some 32% of the respondentsreportsthattheirfiledareusuallyaffectedbytheflashfloodsonce in a year. A small portion of the respondents also report that their fields are three and four times affected by the flash floods. There spondents of the FGDs report that floods in the study area mainly occur in the spring and summer seasons.

Table5:Nooftimesagriculturefieldsaffectedbyflashfloods

NoofTimesfield affected	*Frequency*	*Percentage*
OneTime	**101**	***32.58***
Twotimes	**162**	***52.26***
ThreeTimes	**23**	***7.42***
Four Times	**15**	***04.84***
AboveFour times	**09**	***02.90***
Total	***310***	***100***

Source:Fieldsurvey,2021

Depth-damagefunctionforagriculturefields

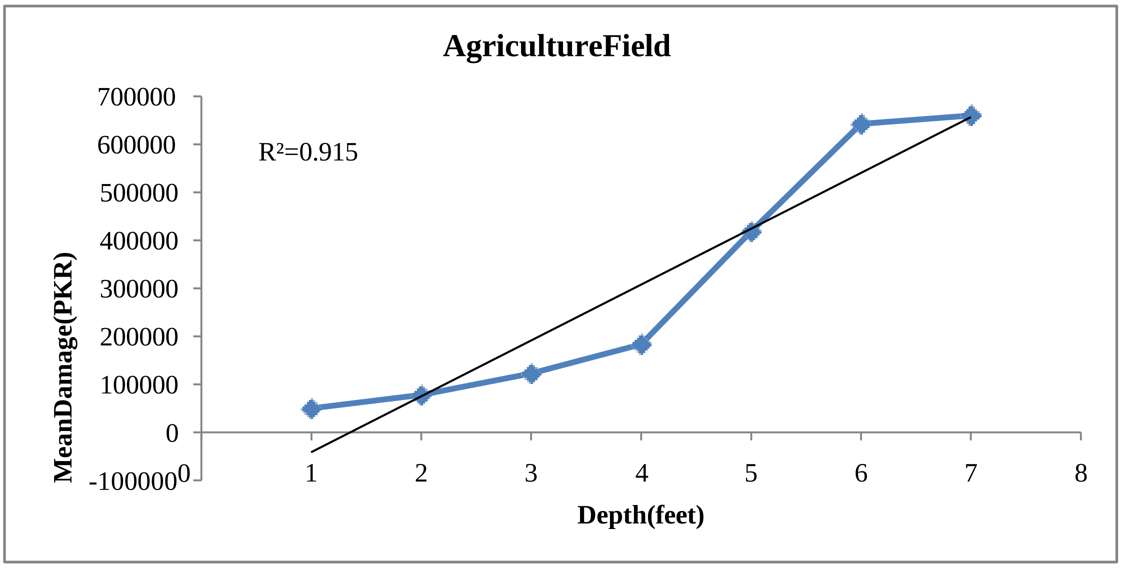
The flashflood erodes the already fertile soil of the agriculture fields. Similarly the sediment load from the upper region in the flood water deposits in the channel bed and on the agriculture fields. Due to its high velocity the flood water also destroy the boundaries of the agriculture plots. To make the lands cultivable the farmers would repairitata cost. Some other factors that influence the overall damage cost are the increased fuel prices and labor cost.

The data regarding damage to the agriculture land collected from the field is displayed in table 6. Based on data in Table 6 a depth damage curve (fig 3) is produced for the damage to agriculture fields. As shown in the fig 3the damage increases gradually along the upslope till the water level reaches 4 feet of height. This is an indication that the flood water until this level does not carry huge load hence damage to agriculture fields are also minimal. A markedriseisobservedintheslopeofthecurveasthewaterlevelrisesfrom4 feet beyond up to 6 feet. This shows that as the water level increases the sediment content of the water also increase thus making the damage huge. However the average damage becomes insignificantly negligible as the water level rises from 6 feet beyond. This suggests that maximum damage to the agriculture fields has already occurred at lower heights. Overall an interesting relationship is observed as the water depth increases the damage to agriculture fields also increases. Statistically as shown by the R^2 (0.915) value a strong positive correlation exists indicating that with the increase in water depth would increase the potential damage.

Table6:damageto agriculture fields

DEPTHOFF LOOD WATER(FEET)	MEAN DAMAGE PKR	SE	MINIMU M DAMAGE PKR	MAXIMU M DAMAGEP KR
1	49837g	1244	20000	**70000**
2	77765f	1366	41000	**120000**
3	122643e	2341	80000	**176000**
4	183267d	3787	100000	**280000**
5	417713c	4195	329000	**550000**
6	642459b	6038	530000	**721000**
7	660071ab	6303	530000	**780000**
TOTAL	**352924**	**9348**	**20000**	**780000**

Figure3:Depth-DamagecurvesforAgricultureFields



Depth-DamageFunctionforAgricultureCrops

Data from the field suggests that the minimum average damage (Rs 100000) to standing crops occurs at a water depth of 1 foot. Likewise the maximum average damage (Rs 989000) occurs at a water depth of 7 feet. The average damage to crops increases with the increase in depth of flood water. The data indicate that correlation exists between water depth and increased damage to standing crops.

Table7:Depth damage data for agriculture crops

WaterDepth in Feet	Mean DamagesRs	SE	Min DamagesRs	Max Damages Rs
1	205704 d	10852	100000	**500000**
2	244490 d	11251	145000	**630000**
3	335296 c	10067	180000	**700000**
4	417041 b	8811	300000	**750000**
5	567520 a	11451	390000	**900000**
6	575327 a	11395	398000	**900000**
7	585939 a	12206	398000	**989000**
Total	**439733**	**6652**	**100000**	**989000**

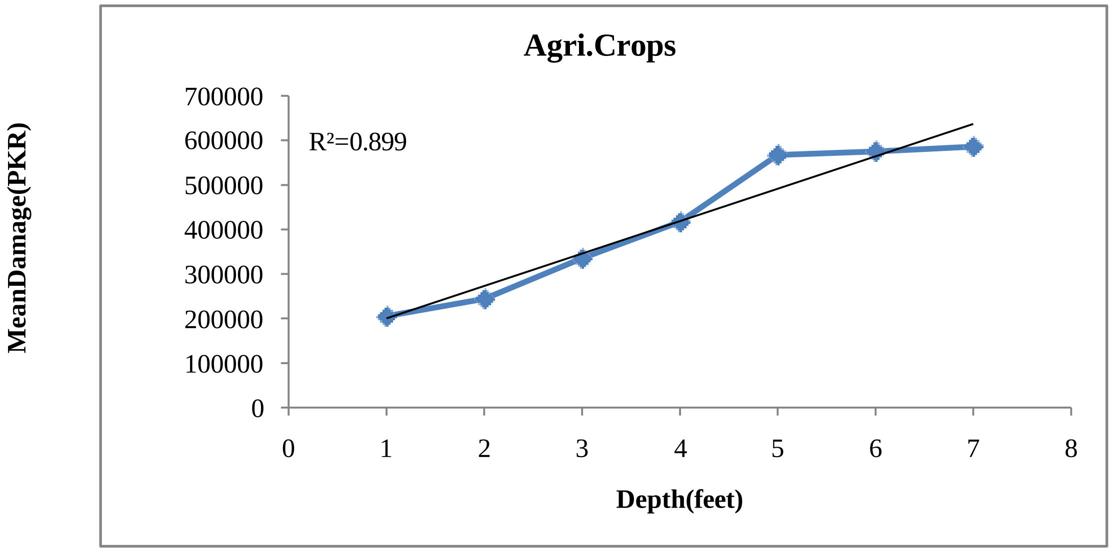
Averageexchangerate2021,1US$=162.97Rs, **Source:Fieldsurvey,2021.**

A significant damage to agriculture crops occur as the water level raise to 1 ftand continues to increase at a steadyproportion up to water level 4ft. however as the water level surpasses the 4ft a sharp shift in damage is seen.When the flood water exceeds 5 ft the damage to crops becomes insignificant this suggests that majority of the crops grown in the area are less than 5 feet in height and a flood of water level 5 and above feet will destroymaximum of it. Shrestha et al. 2018 in their study estimates certain critical levels of water height for complete damage of rice plant. However Martinez-Gomariz et al., (2020) assumes that a water level of 6 feet high will damage the whole agriculture sector of an area which is also confirmed by Pucciariello andPerata (2012) in their study which states that when crops are submerged in water its oxygen intake becomes limited ultimately crops are destroyed.

Thusa strong linear correlation (R^2=0.899) exists between the water depth and damage to crops.During interviews and focus group discussions it has come to the information that majority of the crops and vegetables submerge with a relativelyless water. Theyalso points to the fact that in the low lyingareas the flood water remains stagnant for days resulting in causing diseases in the standing crops and vegetables thus affecting crops yield. The above behavior aligns with the concept that shallow water causes significant damage to submerging crops. Further the water logging also affect the growth causing loss in the yield.

Theyfurther highlights that usuallyflash floods in the area occur at the time when crops are in the production stage. That is why loss is high to agriculture sector. Khan et al. (2011) in their study consider kharif and maize tobethemostsusceptiblecropsandthereasonisthatwhenitreachesmaturity floodsseasonapproaches.Theofficialsoftheagriculturedepartmentpointedthatfloodwaterusuallybringsweedsseedswhichthengrowsinthecropsthus negatively affect the productivity.

Figure4:Depth-Damagecurvesforagriculturecrops



Conclusion

To conclude the work several key findings and implication can be drawn from the analysis of data presented. The agriculture field shave been extended to the main water channel which ultimately narrows down the main channel causing theflashfloods.Flashfloodisarecurrentphenomenonthusimpactingcropsof most of the farmers twice year. The main crops growing in the study area are Maize, wheat, a variety of vegetables and some orchards. Agriculture is the main source of livelihood for most of the population of the study area. The damage to agriculture sector of the area has not only short term implications but have long term negative impacts on the food security and resilience of the community. Effective flood risk management strategies and policies are essential to be formulated for the agriculture sector of the area. Recommendations include the prevention of encroachment towards the main water channel. The farmers need to adapt to the climate change by using more resistant crops so as to minimize the agriculture damage. Structural mitigation measures including the construction of dikes need to be taken, and the provision of community based disaster risk capacity building trainings are to be taken so that people are equip in the wake of any disaster. The community also needs a comprehensive early warning system which will ultimately reduce the damage due to flash flood. The study further finds that a significant area of agriculture particularly adjacent to the main water channel is vulnerable to varying intensity of flash floods.

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