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MODEL OF THE LINKAGE BETWEEN LAND COVER CHANGES TO WATER DISCHARGE AND FOOD PRODUCTIVITY: THE CASE OF THE KONAWEHA WATERSHED IN INDONESIA

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Abstract: Changes in watershed land cover have an impact on reducing water discharge, as well as other derivative impacts such as the productivity of food crops, horticulture, and plantations. This study tries to offer a conceptual model of the effect of changes in watershed land cover, water discharge, and food productivity through food crops, horticultural crops, and plantation crops. This study uses a quantitative approach based on time series data between 2002 and 2021. Data is analyzed using a structural model approach with SEM-SmartPLS software. As a result, changes in land cover have a significant effect on water discharge, but they have no effect on food productivity. Water discharge has a significant effect on food production, and changes in land cover greatly affect food productivity through the role of intermediary variables (mediation) of water discharge. In 2041, changes in land cover can reduce water discharge by around 47.9%. Then the water discharge is estimated to have an impact on the productivity of food crops by 62.3%, vegetable productivity by around 45.7%, and plantation crop productivity by around 72.7%.

Keywords: model; land cover; water discharge; food productivity

1. Introduction

Food is currently one of the world's crucial issues, especially regarding availability (production) and distribution. This is important because it is related to the problem of poverty. Realizing this, the United Nations (2018) has emphasized food as one of the 17 sustainable development goals (SDGs) which are closely related to poverty, adequacy (consumption), production, and distribution.

Food problems cannot be separated from population growth. Population growth that continues to increase goes hand in hand with an increase in food consumption. According to previous studies (Ağızan & Bayramoğlu, 2021; Candar et al., 2021; Sattari et al., 2020; Tang

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et al., 2022), these problems arise because, at the same time, there is a decrease in the quality of watershed resources as a source of irrigation. If watershed resources are used beyond their carrying capacity, it will cause problems with the availability of water discharge for irrigation which will ultimately have an impact on decreasing food production.

The world community through the United Nations predicts that the world population in 2030 will increase significantly, with concentrations in non-agricultural urban areas (United Nations, 2018). This means that the population engaged in the agricultural and food sectors will be decrease, which in turn will lead to an imbalance in the population and food availability. In addition, Isgin and Kara (2015) predict that the unequal distribution of food crop production (including agricultural irrigation) can have an impact on farmers' income. Therefore, a key factor in maintaining the availability and distribution of food is preserving the continuity of watersheds as a source of irrigation, starting with controlling changes in land cover, including irrigation management.

Changes in land cover in a watershed followed by a decrease in water discharge is a common phenomenon. Changes in watershed land cover have been going on for quite some time, to be precise in the 1990s as reported by many authors (Guo et al., 2022; Hasddin, 2019; Mathewos et al., 2022; Taufik et al., 2021; Zhai et al., 2022). Even more, other recent findings (Farid et al., 2022; Latue & Rakuasa, 2023; Rahmawaty et al., 2022; Rakuasa & Pakniany, 2022; Ramadhan & Hidayati, 2022; Yulianto et al., 2019; Yusuf et al., 2018) revealed that the patterns and dynamics of land cover change tended to be the same, namely decreasing forest land cover to become mixed gardens, plantations, settlements, and other built-up land. Their study stated that the change in forest land cover has reached 30%, and is expected to experience similar changes in the future. For example, in Tanzania, as reported by Said, Hyandye, Komakech et al. (2021), there has been an increase in the built-up area in watersheds by up to 32%, then agricultural land will increase by around 39%, and forests will shrink by around 6%. Even Zhai et al. (2022) and Said, Hyandye, Mjemah et al. (2021), report that changes in forest land cover in watersheds in China are more than 32%. Furthermore, Zhai et al. (2022) stated that changes in land cover in watersheds, especially for built-up areas, trigger land ownership conflicts such as those that occurred along the Mekong River in China. This river flows through Laos, Myanmar, Thailand, Cambodia, and Vietnam.

The watershed as a water catchment (rain) area is currently unpredictable as a result of land cover changes (Horton et al., 2022). A clear indication is the fluctuating water discharge, which has been shown to be significantly decreasing according to the research done by Amichiatchi et al. (2022), Nathania et al. (2022), and Heryani et al. (2022). It is predicted that the decrease in water discharge will continue to occur along with the rate of land cover change as reported by Gyawali et al. (2022) for the United States (USA), Achugbu et al. (2022) for the African mainland, Gashaw et al. (2018) for Ethiopia, and Said, Hyandye, Mjemah et al. (2021) for Tanzania. The same thing also happens in Asia in general as stated by Zhai et al. (2022), Ye et al. (2021), and Li and Wang (2016). The studies carried out by Guo et al. (2022) in Vietnam, Yadav et al. (2019) in Thailand, and Marhaento et al. (2018) in Indonesia also show that there is a linear relationship between trends in land cover with the rate of decrease in water discharge. This means that the trend of decreasing discharge is a form of response to the dynamics of changes in land cover.

Agriculture, especially food crops, is closely related to the availability of water discharge, and the water discharge itself is closely related to watershed land cover as a water catcher. This fact has been proven by Said, Hyandye, Komakech et al. (2021) who stated in a study that the ability to predict land cover change events will be associated with agricultural productivity. This study was then supported by Wolde et al. (2021) who claim that changes in land cover that occurred were able to degrade the agricultural sector which was characterized by a decrease in area and productivity. The only shortcoming is that the study of Wolde et al. (2021) has not focused on the magnitude of the effect, including the pattern or model of its relationship to each food commodity (plant).

The phenomenon of land cover change also occurs in the Konaweha watershed, which is located in Southeast Sulawesi Province, Indonesia. Changes in land cover in the Konaweha watershed have been going on for a long time. Baco et al. (2011) stated that forest land cover in the Konaweha watershed between 1991 and 2010 decreased by around 18.30%, and for the same period Marwah (2014) reported that forest in the Konaweha watershed decreased by around 23%. Likewise, the research by Andono et al. (2014) for the period between 2000 and 2015 showed that the forest area in the Konaweha watershed decreased by around 3.86%. The same phenomenon also occurs in the surrounding watersheds in Southeast Sulawesi Province, such as in the Tiworo watershed (Hasddin, 2019; Taufik et al., 2021).

From several studies, it is known that changes in land cover that occur in the Konaweha watershed indicate changes in hydrological conditions which in turn disturb irrigation performance inefficiencies. Andono et al. (2014) found that the annual discharge between 2000 and 2010 decreased by around 82 m^3/s, and even 40% of rainwater became surface runoff. Marwah (2014) stated that changes in forest land cover caused an increase in runoff coefficient from 31.40% to 36.30%, resulting in an increase in the maximum discharge (Qmax) from 246 m^3/s to 252.82 m^3/s, and the minimum discharge (Qmin) from 40.82 m^3/s to 36.82 m^3/s. The same thing was reported by Baco et al. (2011) in their study that changes in land use in the Konaweha watershed from 1991 to 2010 had an impact on increasing the runoff coefficient from 31.4% to 45.6%. During the same period, the maximum discharge increased from 246 m^3/s to 284 m^3/s, while the minimum discharge decreased from 40 m^3/s to 24 m^3/s. However, studies by Marwah (2014), Andono et al. (2014), and Baco et al. (2011) have the limitation that they focused on the upstream watershed, and have not made predictions about future events. Therefore, this study takes the entire Konaweha watershed using current information as a basis for predicting changes in land cover and their impact on water discharge and food production in the future.

Departing from the review above, this study aims to present a model of the relationship between (variables) changes in Konaweha watershed land cover, water discharge, and food productivity. The linkage model was built using time series data from 2002 to 2021. The results of this analysis can then be used to predict the magnitude of the influence of future events, namely in 2041.

The novelty of the research lies in the conceptual and mathematical models of the relationship between changes in land cover, water discharge, and food production through food crops, horticultural crops, and plantation crops. Another contribution is predicting the magnitude of the influence between these variables which is useful for formulating strategic efforts in controlling changes in watershed land cover.

2. Materials and methods

2.1. Study area

This study takes a case in the Konaweha watershed which is administratively located in Konawe Regency, Southeast Sulawesi Province, Indonesia (Figure 1). The Konaweha watershed has a very vital role for Konawe Regency in supporting food production and sustainability because this area is the largest contributor to food production in Southeast Sulawesi Province (Central Bureau of Statistics for Southeast Sulawesi Province, 2022; 2016; 2005; 2002).

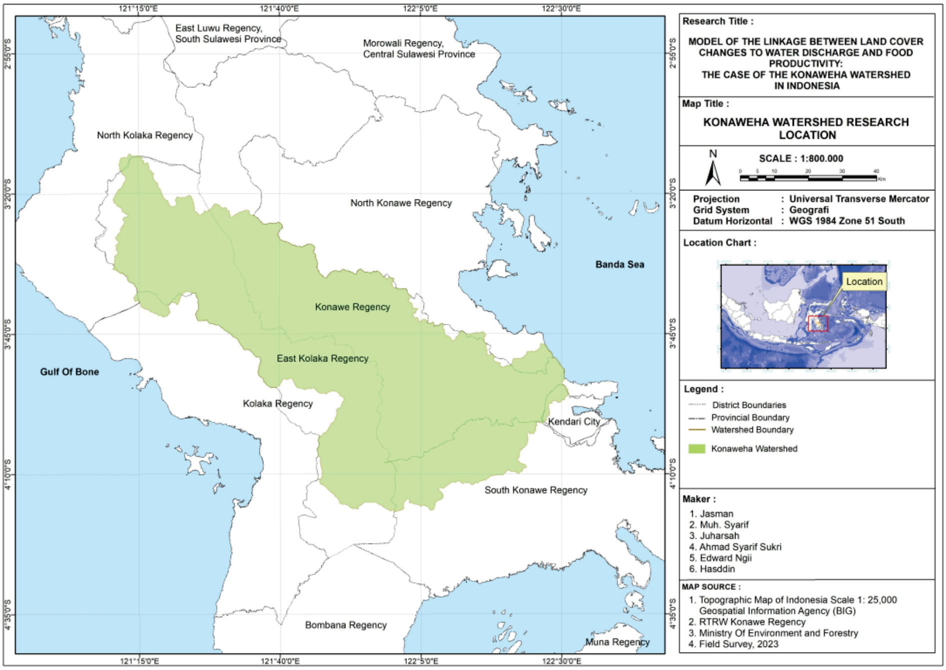

Figure 1. Konaweha watershed.

2.2. Data and methodology

This study uses a quantitative design by presenting statistical data to test the relationship between variables. This approach refers to the opinion of Corbin and Strauss (2015) and Creswell (2014), that one of the characteristics of a quantitative research approach is the processing of statistical data. The processing of statistical data in this study was operationalized in the SEM structural model analysis.

The research data uses a time series between 2002 and 2021. Data is collected from secondary sources from several related agencies, and primary data from survey results. Data on land cover changes in the Konaweha watershed are sourced from satellite imagery, the Konawe District Spatial Plan document (Konawe Regency, 2021), the Ministry of Environment and Forestry (2022), and topographic map at a scale of 1:25,000 (Geospatial Information Agency, 2022). Water discharge data were collected from the Sulawesi River Regional Office IV (2022) in Kendari. Food productivity data were obtained from the Central Bureau of Statistics for Southeast Sulawesi Province (2022, 2016, 2010, 2005, 2002), and from related government agencies, namely the Food Crops, Horticulture, and Plantation Office of Konawe Regency, and the Southeast Sulawesi Provincial.

The primary data in this study are only focused on land cover data for the 2021 Konaweha watershed obtained from survey results. These data are needed to confirm secondary source data. Land cover data were obtained by classifying satellite imagery data for the period 2002 to 2021 with Landsat ETM+ imagery and Landsat imagery. Data analysis was performed using the Object-Based Image Analysis classification method on SAGA software. Then an analysis was carried out to test the reliability of the data (accuracy test) or ground check with conditions referring to the standard confusion matrix. The calculated accuracy tests are overall accuracy, producer's accuracy, and user's accuracy. The overall accuracy threshold value is 85% (Piao et al., 2021; Zulkarnain, 2015).

The relationship model of changes in watershed land cover, water discharge, and productivity as well as predictions of events in 2041 were analyzed using a structural model with Structural Equation Model (SEM) using SmartPLS software. This model is used to obtain the relationships pattern between variables (X to Y). The results of the analysis will point to the strength or magnitude of the causality relationship between variables so that an overview of future predictions can be obtained. The SEM model produces model construction to determine the position of each variable (independent and dependent).

Data were analyzed using a structural model with SEM-SmartPLS software. This was done by testing the model (outer) specifying the relationship between the estimated indicators or parameters and their latent variables (measurement model). Furthermore, the presentation of the structural model or inner model is to specify the causal relationship between latent variables and testing hypotheses.

Outer loading can be seen from the value of Cronbach's Alpha (*CA*) ≥0.70. Then the value of Composite Reliability (*CR*) >0.7 or between 0.6–0.7. The square root value of the Average Variance Extract (*AVE*) ≥0.50. If the measurement results do not meet these requirements, then it is said to be unreliable (Hair et al., 2011).

The interpretation of the results of the hypothesis test refers to the condition conveyed by Hair et al. (2011) that a hypothesis is declared accepted or rejected using the standard test result of an alpha value of 5% (≤0.05), meaning that if the *p*-value is smaller than alpha then the hypothesis is accepted, and vice versa.

3. Result and discussion

3.1. Changes in the land cover of the Konaweha watershed from 2002 to 2021

The results of the analysis of land cover in the Konaweha watershed are classified into seven classes of land cover with their respective area distributions presented in Table 1. The results of the analysis show that between 2002 and 2021 there was a change in land cover with a pattern of decreasing forest land area and increasing settlement area and open land, including dryland farming.

Table 1. Changes in land cover of the Konaweha watershed from 2002 to 2021

Variable	Land cover area (ha)									
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
[TL1] Forest	435,465	431,462	428,108	424,753	421,398	418,044	414,689	411,334	411,583	411,832
[TL2] Dryland farming	118,299	117,949	118,477	119,004	119,531	120,059	120,586	121,114	121,132	121,149
[TL3] Thickets and savanna	92,449	96,658	99,325	101,992	104,659	107,326	109,993	112,661	112,455	112,249
[TL4] Ricefield	23,861	23,861	23,864	23,867	23,870	23,873	23,876	23,879	23,879	23,879
[TL5] Settlements and open land	6,758	6,902	7,059	7,215	7,372	7,528	7,685	7,841	7,781	7,720
[TL6] Pond	376	376	376	377	377	378	378	379	379	379
[TL7] Water body	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700
Total area	678,908	678,908	678,908	678,908	678,908	678,908	678,908	678,908	678,908	678,908

Table 1. Changes in land cover of the Konaweha watershed from 2002 to 2021 (*continued*)

Variable	Land cover area (ha)									
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
[TL1] Forest	412,080	412,329	447,126	445,129	443,131	441,133	439,652	438,171	436,689	430,208
[TL2] Dryland farming	121,167	121,185	101,835	104,066	106,297	108,528	109,966	111,405	112,843	114.281
[TL3] Thickets and savanna	112,043	111,837	98,780	98,104	97,427	96,751	95,880	95,009	94,138	93,267
[TL4] Ricefield	23,879	23,879	23,317	23,664	24,012	24,360	24,563	24,766	24,969	25,172
[TL5] Settlements and open land	7,660	7,600	5,922	5,997	6,073	6,148	6,928	7,607	8,285	8,864
[TL6] Pond	379	379	239	260	280	300	332	364	396	427
[TL7] Water body	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700
Total area	678,908	678,908	678,908	678,908	678,908	678,908	678,908	678,908	678,908	678,908

The area of forest land cover in 2002 was highly dominant, reaching 64.14%, in 2012 it decreased to 60.70%, and in 2021 it rose to 63.37% of the total watershed area. During the period from 2012 to 2021 there was an increase in forest area. According to the survey results, there was a program of reforestation activities from the forest and land rehabilitation program that had been carried out before 2012. The areas that were successfully reforested were generally in the upper reaches of the watershed.

The area of dryland farming in 2002 was around 17% of the total watershed area, decreasing in 2021 to 16.83%. The results of field observations revealed that the decline in dryland farming occurred because some areas turned into settlements and others into open land. This fact is in line with data on residential land cover and open land which shows an increase of around 1% in 2002, 1.14% in 2012, and 1.31% in 2021.

This fact indicates that the Konaweha watershed is already experiencing pressure which may cause changes in hydrological conditions. These results also confirm previous findings by Marwah (2014), Andono et al. (2014), and Baco et al. (2011) that the Konaweha watershed has experienced changes in land cover and decreased hydrological quantity.

3.2. Water discharge for irrigation 2002 to 2021

The result of the subsequent analysis is the development of water discharge in the Konaweha watershed between 2002 and 2021. There is a tendency to decrease the water discharge quite significantly as shown in Figure 2.

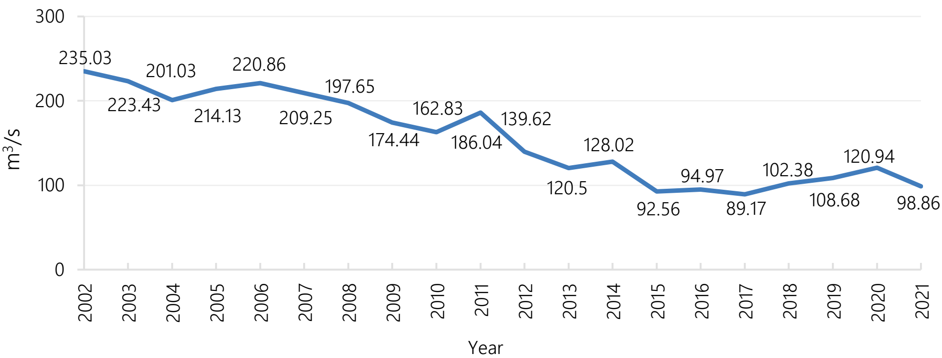

Figure 2. Trends in changes in water discharge in the Konaweha watershed from 2002 to 2021.

The water discharge of the Konaweha watershed in 2002 was 235.03 m^3/s, and in ten years, more precisely by 2011, it fell to 186.04 m^3/s. The decrease in water discharge in the Konaweha watershed continued and was quite significant, thus it was expected to be 98.86 m^3/s in 2021. The water discharge is largely determined by the absorption capacity of the watershed so the decrease in water discharge is closely related to changes in land cover.

3.3. Food productivity in Konawe regency in the period 2002–2021

Agricultural productivity data as a basis for food supply include the productivity of food crops, horticultural crops, and plantation crops. There are seven types of food crops that have consistent data between 2002 and 2021 as presented in Table 2. Horticultural crops include 12 commodities of vegetables (fruits are not normally distributed) as presented in Table 3. Data for plantation crop productivity of as many as eight commodities are shown in Table 4.

Table 2. Productivity of food crops in Konawe Regency from 2002 to 2021

Variable	Productivity of food crops (%)									
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
[KP1] Rice	39.59	39.59	39.59	39.59	39.7	39.93	40.31	40.78	41.57	45.69
[KP2] Corn	17.54	17.54	17.54	17.54	19.61	6.87	25.4	25.88	26.35	26.31
[KP3] Soybeans	7.31	7.31	7.31	7.31	7.54	5.4	9.26	9.13	8.37	8.35
[KP4] Peanuts	8.98	8.98	8.98	8.98	8.21	5.55	8.9	8.95	8.58	8.4
[KP5] Mung beans	8.64	8.64	8.64	8.64	8.73	6.05	8.35	14.44	8.48	8.4
[KP6] Cassava	136.19	136.19	136.19	136.19	134.68	132.1	171.93	173.3	183.78	183.61
[KP7] Sweet potato	109.55	109.55	109.55	109.55	96.78	81.75	84.86	82.7	80.14	80.19
Years Average	46.83	46.83	46.83	46.83	45.04	39.66	49.86	50.74	51.04	51.56
Continuation	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
[KP1] Rice	42.34	43.43	51.24	46.9	38.82	42.74	39.52	38.84	40.08	38.52
[KP2] Corn	19.08	25.45	24.96	28.73	27.93	46.31	42.77	40.43	38.45	68.28
[KP3] Soybeans	9.56	9.45	13.81	19.27	22.58	16.95	19.39	20.51	19.56	58.29
[KP4] Peanuts	6.6	6.72	7.2	15	12.33	12.99	12.72	16.54	14.48	26.55
[KP5] Mung beans	7.76	8.08	8.14	8.06	8.1	8.49	6.29	8.29	9.67	10.3
[KP6] Cassava	168.74	196.3	198.3	250.3	298.41	280.17	251.1	248.6	253.2	392.2
[KP7] Sweet potato	84.2	84.3	91.29	141.7	140.35	161.94	172.4	179.6	138.2	135.45
Years Average	48.33	53.38	56.41	72.84	78.36	81.37	77.74	78.96	73.36	104.23

Table 2 shows the dynamics (increase and decrease) of food crop productivity. Judging by the total production between 2002 and 2021, there was a significant increase in productivity, namely from 46.85% to 104.23%. The productivity of food crops in 2002 was 46.83%, decreasing to 39.66% in 2007. The decline in the productivity of food crops was caused by a decrease in the production of peanuts, green beans, cassava, and sweet potatoes. From 2008 the productivity of food crops showed an increase compared to the previous year, and continued to increase until 2021, reaching 104.23%. Cassava and sweet potato contribute to the highest productivity of food crops. The roles of these two types of commodities are consistent over time. The type of commodity with the lowest productivity is mung beans, but its productivity shows an increase.

The interesting thing is that rice productivity shows a decreasing trend—in 2002 it was 39.59% and in 2021 it fell to 38.52%. It was inversely proportional to the area of paddy fields

(Table 1) which has increased. The survey results show that there are several paddy fields that are no longer used, partly because the owners do not cultivate them anymore, as well as because of a lack of irrigation water.

Table 3. Productivity of vegetables in Konawe Regency from 2002 to 2021

Variable	Productivity of vegetables (%)									
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
[S1] Onion	32.84	36.54	38.79	49.54	34.22	24.04	28.69	23.40	18.98	9.07
[S2] Spinach	41.30	51.49	68.49	43.61	40.58	43.06	47.46	35.58	35.93	4.04
[S3] Beans	6.54	6.91	7.54	3.58	1.51	2.55	2.58	3.77	6.49	8.12
[S4] Chili pepper	61.43	78.39	106.67	70.09	67.87	71.47	80.68	73.95	64.27	6.18
[S5] Cayenne pepper	10.58	15.92	24.81	19.15	21.35	26.41	27.42	30.47	40.49	5.38
[S6] Long beans	21.50	33.09	28.54	24.63	3.40	14.21	18.11	27.26	42.82	34.04
[S7] Water spinach	19.49	21.10	31.58	23.11	8.76	7.36	12.64	14.26	19.08	4.72
[S8] Cucumber	41.38	49.08	79.84	52.45	41.97	50.15	46.50	90.45	83.22	8.87
[S9] Chayote	32.84	29.44	23.80	32.00	26.74	21.39	23.98	13.80	18.64	19.61
[S10] Petsai	80.81	99.33	130.21	82.36	74.10	80.92	84.88	77.67	67.40	7.84
[S11] Eggplant	26.68	39.29	42.45	27.21	26.33	41.20	48.76	60.99	78.20	26.38
[S12] Tomatoes	28.14	33.46	35.14	26.77	14.81	15.64	12.41	21.51	26.32	9.15
Years Average	33.63	41.17	51.49	37.88	30.14	33.20	36.18	39.43	41.82	11.95
Continuation	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
[S1] Onion	8.34	6.89	10.55	10.55	15.09	11.35	11.29	13.44	22.00	32.99
[S2] Spinach	3.80	4.98	1.83	1.83	5.29	6.56	8.77	12.36	17.17	23.21
[S3] Beans	12.29	16.44	16.45	16.45	82.26	9.86	14.83	28.73	47.25	43.00
[S4] Chili pepper	6.16	6.16	4.56	4.56	22.70	36.95	42.95	45.84	41.73	58.16
[S5] Cayenne pepper	5.55	5.49	3.32	3.32	4.18	40.61	40.95	43.25	37.79	65.45
[S6] Long beans	8.28	8.51	4.57	7.50	11.26	29.82	24.98	21.46	23.21	36.59
[S7] Water spinach	6.93	9.09	3.25	3.25	6.64	11.15	9.11	11.97	16.77	24.41
[S8] Cucumber	7.82	7.09	3.88	3.88	13.51	37.34	23.81	25.58	28.92	44.18
[S9] Chayote	18.77	23.27	3.10	3.10	14.26	13.20	20.00	29.50	25.00	33.75
[S10] Petsai	9.00	9.45	5.01	5.01	11.36	11.44	11.72	14.29	18.66	29.58
[S11] Eggplant	11.67	12.54	6.97	6.97	15.47	34.52	21.47	20.99	45.74	51.59
[S12] Tomatoes	8.37	7.41	5.03	5.03	8.67	43.12	31.23	25.67	22.15	41.83
Years Average	8.92	9.78	5.71	5.95	17.56	23.83	21.76	24.42	28.87	40.40

Table 3 shows that the productivity of vegetable crops in Konawe Regency between 2002 and 2021 tended to be stagnant or did not show a significant increase. The total productivity of vegetables in 2002 was 33.63% and in 2021 it was 40.40%, which means that in twenty years it only increased by 6.77%. Vegetable productivity during the period from 2003 to 2005 increased compared to 2001, but then decreased in 2007 until it experienced an extreme decline in 2014. Vegetable productivity began to improve entering the period from 2017 to 2021.

Judging by each commodity, there are types that have good productivity. For example, in case of long beans, its productivity in 2002 was 21.50%, in 2011 it was 34.04%, and in 2021 it rose to 36.59%. Also, the cayenne pepper productivity rate in 2002 was 10.58 and in 2021 it rose to 65.45%, even though there was a decline during the period from 2012 to 2016.

Table 4. Productivity of plantation plants in Konawe Regency from 2002 to 2021

Variable	Productivity of vegetables (%)									
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
[TP1] Palm oil	40.61	40.61	40.61	40.61	40.61	40.61	40.61	40.61	40.61	40.61
[TP2] Coconut	181.43	130.84	57.26	73.06	46.29	43.33	51.7	54.02	97.27	92.98
[TP3] Sago	207.84	78.13	91.33	112.81	96.25	96.32	53.7	56.93	111.86	68.55
[TP4] Coffee	10.06	10.27	24.97	24.18	28.29	23.4	27.72	23.92	50.23	14.19
[TP5] Cacao	47.86	38.16	48.73	41.8	36.87	36.54	39.21	39.81	57.85	52.33
[TP6] Pepper	12.25	52.3	57.63	23.07	33.09	32.29	33.62	35.96	37.82	22.03
[TP7] Cashew	24.38	16.18	50.42	45.76	53.23	42.7	36.59	47.21	33.77	20.24
[TP8] Clove	29.82	22.71	10	56.12	17.1	16.86	18.02	29.5	18.22	5.63
Years Average	69.28	48.65	47.62	52.18	43.97	41.51	37.65	41	55.95	39.57
Continuation	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
[TP1] Palm oil	7.51	38.46	23.47	19.59	25.53	25.53	30.69	40.34	64.89	92.77
[TP2] Coconut	113.29	103.35	49.65	83.83	63.59	79.36	90.4	97.63	95.53	96.94
[TP3] Sago	124.25	122.45	112.62	112.62	104.68	104.68	113.14	233.2	123.63	123.55
[TP4] Coffee	32.9	18.1	17.88	35.68	36.68	20.24	20.4	29.95	35.79	36.95
[TP5] Cacao	61.36	64.35	63.23	63.26	63.39	62.07	58.28	65.84	67.13	61.33
[TP6] Pepper	38.06	36.11	35.1	40.27	32.84	29.78	30.36	36.19	39.08	39.17
[TP7] Cashew	35.09	49.78	34.46	34.46	33.64	33.64	34.98	46.16	50.63	49.96
[TP8] Clove	35.83	33.39	30.57	30.57	27.59	27.59	22.99	20.35	21	22.27
Years Average	56.04	58.25	45.87	52.54	48.49	47.86	50.16	71.21	62.21	65.37

Table 4 shows that the productivity of plantation crops in Konawe Regency between 2002 and 2021 decreased from 69.28% to 65.37%. The productivity of plantation crops between 2003 and 2018 was lower than the productivity in 2002 with an extreme decline occurring in 2011. The productivity of plantation crops increased in 2019, but then decreased in 2020 and 2021.

3.4. The effect of changes in watershed land cover, water debit, and food productivity

Based on the data and facts presented in Tables 1 to 4, as well as in Figure 2, a linkage or influence test was carried out between the variables: changes in land cover, water discharge, and food productivity. The offered model of the conceptual framework is shown in Figure 3.

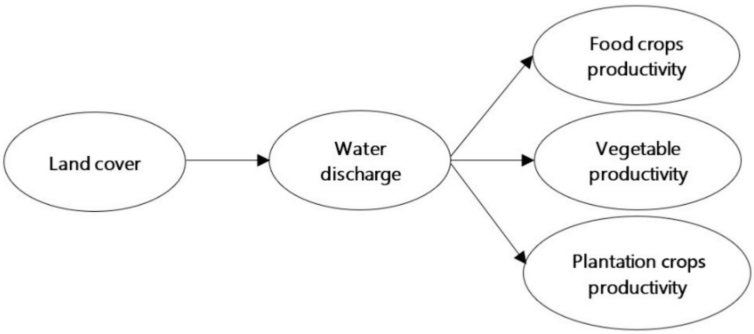

Figure 3. Conceptual model of the effect of land cover and water discharge on the productivity of food crops, vegetables, and plantation crops.

In accordance with the built model, the independent variables (X) consist of land cover (X1) and water discharge (X2). The dependent variable (Y) is the food productivity portion of food crops (Y1), vegetables (Y2), and plantation crops (Y3). The water discharge variable in the model is constructed as a dependent variable (Y) for its influence by land cover (X), as well as mediation (Z) between land cover and productivity.

3.4.1. Direct influence model

This analysis is needed to determine the relationship pattern (influence) of watershed land cover and water discharge on food crop productivity, vegetable productivity, and plantation crop productivity. The hypotheses proposed are as follows:

- H_1: Land cover has a significant effect on water discharge;
- H_2: Land cover has a significant effect on the productivity of food commodity crops;
- H_3: Land cover has a significant effect on the productivity vegetable commodity;
- H_4: Land cover has a significant effect on the productivity of plantation crop commodities;
- H_5: Water discharge has a significant effect on the productivity of food crops commodity;
- H_6: Water discharge has a significant effect on the productivity of vegetable commodities; and
- H_7: Water discharge has a significant effect on the productivity of plantation crops commodities.

In an effort to improve (strengthen the data reliability) of the model, indicators that meet the criteria will be used at the advanced stage, so that indicators that are inappropriate (have weak outer loading values) are excluded from the model. According to the results of the analysis, it is known that there are four indicators of land cover (TL) that meet the assessment criteria (having a strong outer loading value), namely: TL2—Dry land agriculture and plantations; TL3—Shrubs and savanna; TL6—Ponds, and TL7—Bodies of water. There are eight indicators for the water discharge variable that meet the criteria, namely: D1—January; D2—February; D3—March; D4—April; D5—May; D6—June; D8—August; and D12—December. There are five indicators for the food commodity variable (KP), namely: KP2—Corn; KP3—Soybeans; KP4—Peanuts; KP6—Cassava; and KP7—Sweet Potato. The indicators for the vegetable crop variable (S) fulfill as many as seven indicators, namely: S1—Onions; S4—Chili pepper; S7—Water spinach; S8—Cucumber; S9—Chayote; S10—Petsai; and S11—Eggplant. The last one is an indicator on the plantation crop variable (TP) which meets only one assessment criterion, namely the TP5—Cacao indicator.

The second stage is the analysis of the inner model, namely the analysis that aims to show the specification of the causal relationship between latent variables (structural model) and to test the hypotheses. The inner model analysis informs construct reliability and validity which presents *CA*, *CR*, and *AVE* values as seen in Table 5.

Table 5 shows that the *CA* value for the land cover variable is 0.877, then the water discharge is 0.956; productivity of food crops (commodities) is 0.948; vegetable productivity 0.929; and plantation crop productivity 1.000. This indicates that the *CA* value has met because it exceeds or > 0.6. Second, the *CR* value of the land cover variable is 0.917; water discharge of 0.965; productivity of food crops 0.962; vegetable productivity 0.943; and plantation crop productivity of

Table 5. Construct reliability and validity

Variable	*CA*	*CR*	*AVE*
Water discharge	0.956	0.965	0.777
Crops/food commodities	0.948	0.962	0.854
Vegetable crops	0.929	0.943	0.707
Plantation crops	1.000	1.000	1.000
Land cover	0.877	0.917	0.757

1.000. This means that the resulting value meets the required standard, which is at least 0.7. Third, the *AVE* value of the land cover variable is 0.757; water discharge 0.777; food crop productivity 0.854; vegetable productivity 0.707; and plantation crop productivity 1.000. This value is stated to have fulfilled the assessment criteria, namely ≥ 0.50.

Next, the results of the R-Square test are presented. This value ranges from 0 to 1, to explain the magnitude of the combination of independent variables (together) in influencing the dependent variable. The results of the R-Squared analysis are shown in Table 6.

Table 6. R-squared

Variable	R-Square	R-Square Adjusted
Water discharge	0.479	0.450
Crops/food commodities	0.623	0.579
Vegetable crops	0.457	0.393
Plantation crops	0.727	0.695

The magnitude of the influence of land cover on water discharge that can be explained is around 47.90% (52.10% is explained by variables and indicators other than this model), so that the land cover variable has an effect on water discharge of 47.90%. Furthermore, the effect of land cover and water discharge on food crop productivity is 62.30%, and the land cover variable has an effect on food crop productivity of 62.30%. Land cover affects the productivity of vegetables by 45.70%. Land cover has an influence on the productivity of plantation crops around 72.70%. This result is in line with the reports in the studies by Gyawali et al. (2022), Achugbu et al. (2022), Gashaw et al. (2018), Said, Hyandye, Mjemah et al. (2021), Zhai et al. (2022), Ye et al. (2021), Li and Wang (2016), Guo et al. (2022), Yadav et al. (2019), and Marhaento et al. (2018) that there is a relationship between the effect of changes in land cover and the rate of decrease in water discharge, meaning that the decrease in discharge is a result of changes in watershed land cover. The following coefficient, displayed in Table 7, represents the final analysis output of hypothesis testing.

Table 7. Path coefficient testing the direct effect hypothesis

Variable	Original Sample (*O*)	Sample Mean (*M*)	Standard Deviation (*SD*)	T Statistic (*O/SD*)	*p*-value
Water discharge -> Food commodities	–0.625	–0.616	0.168	3.711	0.000
Water discharge -> Vegetable crops	0.603	0.626	0.249	2.424	0.016
Water discharge -> Plantation crops	–0.801	–0.794	0.160	5.018	0.000
Land cover -> Water discharge	0.692	0.709	0.070	9.938	0.000
Land cover -> Food commodities	–0.216	–0.276	0.232	0.929	0.353
Land cover -> Vegetable crops	1.000	0.084	0.336	0.296	0.767
Land cover -> Plantation crops	–0.072	–0.079	0.190	0.380	0.704

A hypothesis is declared accepted if the *p*-value is at least 5% or ≤0.05 and it is rejected if the *p*-value is greater than the threshold value (Hair et al., 2011). Based on these criteria, the results of the analysis in Table 7 show that land cover has a positive and significant effect on water discharge, so the first hypothesis (H_1) proposed that land cover has a significant effect on water discharge is proven or accepted (H_a). Furthermore, land cover has no significant effect on productivity of food commodity crops, so the second hypothesis (H_2) is not proven i.e., it is rejected (H_0). Land cover does not have a significant positive effect on the productivity of vegetable commodities, meaning that the third hypothesis (H_3) proposed is not proven (H_0). Land cover has no effect on the productivity of plantation commodity, so the fourth hypothesis (H_4) is not proven, i.e., it is rejected (H_0). Water discharge has a significant effect on the productivity of food commodity so the proposed hypothesis (H_5) is proven or accepted (H_a). The effect of water discharge on vegetable productivity has a significant effect, which means that the proposed hypothesis (H_6) is proven or accepted. The effect of water discharge on the productivity of plantation crops commodity has a significant effect, so the proposed hypothesis (H_7) is proven (H_a).

The results of the analysis are then interpreted into a mathematical model in the form of a bootstrap equation. The resulting model is at the same time a research strength as well as a position for research novelty, namely as follows:

- Land cover (*TL*) to water discharge (*D*) the regression model is: $TL = 0.692\ D$;
- Land cover on the productivity of food crop commodities (*KP*), the regression equation model is: $TL = –0.216\ KP$;
- Land cover on vegetable commodity productivity (S), the regression model: $TL = 1.000$ S;
- Land cover on the productivity of plantation commodities (*TP*), can be formulated as the regression equation $TL = –0.072\ TP$;
- From the land cover bootstrap equation (*TL*) to water discharge (*D*), food crop productivity (*KP*), vegetable productivity (*S*), plantation crop productivity (*TP*) in the H_1 to H_4 hypotheses, the regression equation can be formulated as follows:

$$TL = 0.692\ D – 0.216\ KP + 1.000\ S – 0.072\ TP \tag{1}$$

- Water discharge (*D*) on the productivity of food crop commodities (*KP*) the formulated the regression equation is D = –0.625 KP;
- Water discharge (*D*) to vegetable commodity productivity (*S*) the regression equation model is $D = 0.603\ S$;
- Water discharge (*D*) to the productivity of plantation crop commodities (*TP*) the regression equation model $D = –0.801\ TP$; and
- From the water discharge bootstrap equation (*D*) on food commodity productivity (*KP*), vegetable commodity productivity (*S*), plantation crop commodity productivity (*TP*) in hypotheses H_5 to H_7 the regression equation is formulated as follows:

$$D = –0.625\ KP + 0.603\ \mathrm{S} –0.801\ \mathrm{TP} \tag{2}$$

3.4.2. Model of indirect influence of changes in land cover on the productivity of food crops, vegetables, and plantation crops through water discharge mediation

There are three hypotheses proposed to be tested in this model. The first is that land cover has a significant effect on the productivity of food crops through the mediation of water discharge (H_8). The second is that land cover has a significant effect on vegetable productivity through the mediation of water discharge (H_9). The third is that land covers have a significant effect on the productivity of plantation crops through the mediation of water discharge (H_{10}). The results of the analysis of the indirect (mediation) effect hypothesis testing are presented in Table 8.

Table 8. Specific indirect effect hypothesis testing

Variable	*O*	*M*	*SD*	*O/SD*	*p*-value
Land cover -> Water discharge -> Food commodities	–0.432	–0.411	0.146	2.965	0.003
Land cover -> Water discharge -> Vegetable crops	0.417	0.440	0.181	2.303	0.022
Land cover-> Water discharge -> Plantation crops	–0.554	–0.559	0.116	4.784	0.000

The *p*-value of each effect of land cover on plant productivity through water discharge is 0.003 so the hypothesis (H_8) is proven or accepted (H_a). Then the effect of land cover on vegetable productivity through the mediation of water discharge is 0.022, so the hypothesis (H_9) is proven or accepted (H_a). Finally, the effect of land cover on the productivity of plantation crops through the mediation of water discharge is 0.000, so the tenth hypothesis (H_{10}) is proven or accepted (H_a).

The indirect relationship model, namely the mediation role of water discharge in conditioning the effect of changes in land cover on food productivity (food crop commodities, vegetables, and plantation crops) can be interpreted into the following bootstrap equation:

- Land cover (*TL*) on food crop productivity (*KP*) through the mediation role of water discharge (*D*) for H_8 with the regression equation model as: $KP = –0.432\ TL –0.216\ D$;
- Land cover (*TL*) on the productivity of vegetable commodities (*S*) through the mediation of water discharge (*D*), for H_9 the regression equation model is: $S = 0.417\ TL + 1.000\ D$; and
- Land cover (*TL*) on the productivity of plantation crop commodities (*TP*) through the mediation of water discharge (*D*), for H_{10}, the regression equation model is: $TP = –0.554\ TL –0.072\ D$

Water discharge plays a very important role in maintaining food productivity in each of the food crop commodities, vegetables, and plantation crops. Changes in land cover in the watershed must be controlled to maintain the availability of water discharge (maximizing rainwater input). At the same time management of discharge for irrigation is also important to ensure that water can be distributed evenly to agricultural lands. The water discharge management approach does not only maintain the need for water for each food commodity, but it can reduce the direct impact of changes in land cover on food productivity. Thus, food products can be maintained and be able to meet food needs.

3.5. Predictions of the effect of changes in watershed land cover, water discharge, and food productivity

Relationship models that are proven to have a significant effect can be used to represent future events. This assumption is used based on two reasons: (a) the database used is a time series for 20 years (2002 to 2021), and (b) the relationship between changes in land cover, water discharge, and productivity is a manifestation of a causal relationship so that the current conditions will determine future events.

Based on this logic, changes in land cover have an impact on water discharge (R-Square = 0.479%), meaning that if the land cover of the Konaweha watershed continues to change (same pattern 2002 to 2021) for the next 20 years, it will result in a decrease in water discharge in 2041 of around 47.90%. This is very likely to occur because the results of the hypothesis testing proved to be significant.

The decrease in water discharge will affect the productivity of food crops in 2041 by 62.30% (R-square value), meaning that the types of food crops that increased during the period 2002–2021 will increase in 2041 to around 62.30% and vice versa. A decrease in water discharge in 2041 will also have an impact on vegetable productivity of around 45.70%, and on plantation crop productivity of around 72.70%.

4. Conclusion

Based on the results of an analysis of the dynamics of changes in land cover, water discharge in the Konaweha watershed, and food productivity, a conceptual model is produced, namely land cover changes have a direct impact on water discharge. Changes in land cover do not directly affect the productivity of food crops for each of the commodities analyzed. Water discharge has a direct influence on food productivity in each commodity. The water debit acts as a mediation or can condition the direct impact of changes in land cover on food productivity.

Control of land cover changes that occur in the Konaweha watershed is absolutely carried out by referring to the pattern of changes that have been disclosed; otherwise, it will have an impact on reducing discharge in the future up to 47%. The decrease in water discharge then has an impact on reducing food productivity for each commodity so that it disrupts the supply and distribution of food needed for the population.

Strategic efforts that need to be carried out as soon as possible are directed to the irrigation area manager, in this case, the Kendari River Region IV Office, Ministry of Public Works of the Republic of Indonesia to intervene in irrigation management. For example, with engineering management of irrigation sluice openings so that water distribution is effective and efficient, as well as other technical approaches according to needs in the field. To support this, further studies are needed to help academically regarding technical management models and conditional matters. This is important to answer the existing problems, not only in the study locations, but in every place or country that has the same problems.

This research has limitations. First, it is still only a prediction, so further analysis is needed to strengthen this finding by using more powerful analysis tools. Second, it has not disclosed the impact of changes in land cover, decreased water discharge, and the productivity of food commodities on socio-economy. Therefore, future studies can examine this from both a qualitative (phenomenal), quantitative, or combined (mixed) perspective to make it more comprehensive.

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References

Achugbu, I. C., Olufayo, A. A., Balogun, I. A., Dudhia, J., McAllister, M., Adefisan, E. A., & Naabil, E. (2022). Potential effects of Land Use Land Cover Change on streamflow over the Sokoto Rima River Basin. *Heliyon*, *8*(7), Article e09779. https://doi.org/10.1016/j.heliyon.2022.e09779

Ağızan, S., & Bayramoğlu, Z. (2021). Comparative Investment Analysis of Agricultural Irrigation Systems. *Journal of Tekirdag Agricultural Faculty*, *18*(2), 222–233. https://doi.org/10.33462/jotaf.745548

Amichiatchi, N. J. M. C., Soro, G. E., Hounkpè, J., Goula Bi, T. A., & Lawin, A. E. (2022). Evaluation of Potential Changes in Extreme Discharges Over Some Watersheds in Côte d'Ivoire. *Hydrology*, *10*(6), 1–16. https://doi.org/10.3390/hydrology10010006

Andono, R., Limantara, L. M., & Juwono, P. T. (2014). Studi Penilaian Indikator Kinerja DAS Konaweha Akibat Perubahan Tata Guna Lahan Berdasarkan Kriteria Hidrologis [Assessment of Konaweha Watershed Performance Indicators Due to Changes in Land Use Based on Hydrological Criteria], *Jurnal Teknik Pengairan, 5*(1), 54–60. https://jurnalpengairan.ub.ac.id/index.php/jtp/article/view/204

Baco, S. L., Sinukaban, N., Purwanto, Y. J., Sanim, B., & Tarigan, S. D. (2011). Pengaruh Perubahan Penggunaan Lahan Terhadap Kondisi Hidrologi DAS Konaweha Hulu Provinsi Sulawesi Tenggara [The

Effect of Changes in Land Use on the Hydrological Conditions of the Konaweha Hulu Watershed in Southeast Sulawesi Province]. *Jurnal Agroteknos*, *1*(3), 163–172. https://adoc.pub/pengaruh-perubahan-penggunaan-lahan-terhadap-kondisi-hidrolo.html

Candar, S., Korkutal, I., & Bahar, E. (2021). Changes of Vine Water Status and Growth Parameters Under Different Canopy Managements on cv. Merlot (Vitis vinifera L.). *Journal of Tekirdag Agricultural Faculty*, *19*(1), 1–15. https://doi.org/10.33462/jotaf.795232

Central Bureau of Statistics for Southeast Sulawesi Province. (2022). *Southeast Sulawesi Province in Figures 2022*. Central Bureau of Statistics. https://sultra.bps.go.id/publication/2022/02/25/b5383ab2887274d3ee7f0034/provinsi-sulawesi-tenggara-dalam-angka-2022.html

Central Bureau of Statistics for Southeast Sulawesi Province. (2016). *Southeast Sulawesi Province in Figures 2016*. Central Bureau of Statistics. https://sultra.bps.go.id/publication/2016/07/15/060fb0685c3ebce62b0ad4d3/provinsi-sulawesi-tenggara-dalam-angka-2016.html

Central Bureau of Statistics for Southeast Sulawesi Province. (2010). *Southeast Sulawesi Province in Figures 2010*. Central Bureau of Statistics. https://sultra.bps.go.id/publication/2011/04/08/e76d6b4c86171fa275c1e497/sulawesi-tenggara-dalam-angka-2010.html

Central Bureau of Statistics for Southeast Sulawesi Province. (2005). *Southeast Sulawesi Province in Figures 2005*. Central Bureau of Statistics. https://sultra.bps.go.id/publication/2009/01/01/23f3ebf246dce0c3f509e571/sulawesi-tenggara-dalam-angka-2005-2006.html

Central Bureau of Statistics for Southeast Sulawesi Province. (2002). *Southeast Sulawesi Province in Figures 2002*. Central Bureau of Statistics. https://sultra.bps.go.id/publication/2003/08/01/3cd3b89bf83686c8b1009351/sulawesi-tenggara-dalam-angka-2002.html

Corbin, J., & Strauss, A. (2015). *Basics of Qualitative Research* (4th ed.). Sage Publications Ltd.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed). SAGE Publications.

Farid, M., Pratama, M. I., Kuntoro, A. A., Adityawan, M. B., Rohmat, F. I. W., & Moe, I. R. (2022). Flood Prediction due to Land Cover Change in the Ciliwung River Basin. *International Journal of Technology, 13*(2), 356–366. https://doi.org/10.14716/ijtech.v13i2.4662

Gashaw, T., Tulu, T., Argaw, M., & Worqlul, A. W. (2018). Modeling the hydrological impacts of land use/land cover changes in the Andassa watershed, Blue Nile Basin, Ethiopia. *Science of the Total Environment*, *619–620*, 1394–1408. https://doi.org/10.1016/j.scitotenv.2017.11.191

Geospatial Information Agency. (2022). *Indonesia/Southeast Sulawesi* (Topographic map, 1:25,000). Retrieved July 5, 2022 from https://geoportal.big.go.id/#/viewer

Guo, X., Ye, J., & Hu, Y. (2022). Analysis of Land Use Change and Driving Mechanisms in Vietnam during the Period 2000–2020. *Remote Sensing*, *14*(7), Article 1600. https://doi.org/10.3390/rs14071600

Gyawali, B., Shrestha, S., Bhatta, A., Pokhrel, B., Cristan, R., Antonious, G., Banerjee, S., & Paudel, K. P. (2022). Assessing the Effect of Land-Use and Land-Cover Changes on Discharge and Sediment Yield in a Rural Coal-Mine Dominated Watershed in Kentucky, USA. *Water*, *14*(4), Article 516. https://doi.org/10.3390/w14040516

Hair, J. F., Ringle, C. M., & Sarstedt, M. (2011). PLS-SEM: Indeed a Silver Bullet. *Journal of Marketing Theory and Practice*, *19*(2), 139–152. https://doi.org/10.2753/MTP1069-6679190202

Hasddin, H. (2019). Karakteristik Sumberdaya Alam dan Rencana Pengelolaan DAS Tiworo Kabupaten Muna Barat [Characteristics of Natural Resources and Management Plan for the Tiworo Watershed, West Muna Regency]. *Jurnal Aksara Public*, *3*(2), 149–159. http://aksarapublic.com/index.php/home/article/view/216/213

Heryani, N., Kartiwa, B., Sosiawan, H., Rejekiningrum, P., Adi, S. H., Apriyana, Y., Pramudia, A., Yufdy, M. P., Tafakresnanto, C., Rivaie, A. A., Suratman, S., Dariah, A., Malik, A., Yusuf, Y., & Setiani, C. (2022). Analysis of Climate Change Impacts on Agricultural Water Availability in Cimanuk Watershed, Indonesia. *Sustainability*, *14*(23), Article 16236. https://doi.org/10.3390/su142316236

Horton, A. J., Triet, N. V. K., Hoang, L. P., Heng, S., Hok, P., Chung, S., Koponen, J., & Kummu, M. (2022). The Cambodian Mekong floodplain under future development plans and climate change. *Natural Hazards and Earth System Sciences*, *22*(3), 967–983. https://doi.org/10.5194/nhess-22-967-2022

Isgin, T., & Kara, F. O. (2015). Impacts of the Harran Plain Irrigation Projects on the well-being of Local Cotton Farmers Operating in the Sanliurfa Province of Turkey: Income Distribution Revisited. *Journal of Agricultural Sciences*, *21*(4), 483–491. https://doi.org/10.1501/Tarimbil_0000001351

Konawe Regency. (2021). *Peraturan Daerah (PERDA) Kabupaten Konawe Kepulauan Nomor 2 Tahun 2021 tentang Rencana Tata Ruang Wilayah Kabupaten Konawe Kepulauan Tahun 2021-2041* [Regional Regulation (PERDA) of Konawe Islands Regency Number 2 of 2021 concerning the Spatial Plan for the Konawe Islands Regency for 2021-2041]. https://peraturan.bpk.go.id/Home/Details/227059/perda-kab-konawe-kepulauan-no-2-tahun-2021

Latue, P. C., & Rakuasa, H. (2023). Spatial Dynamics of Land Cover Change in Wae Batu GantungWatershed, Ambon City, Indonesia. *International Journal of Scientific Multidisciplinary Research, 1*(3), 117–130. https://doi.org/10.55927/ijsmr.v1i3.3623

Li, L., & Wang, Y. (2016). Land Use/Cover Change from 2001 to 2010 and its Socioeconomic Determinants in Guangdong Province, A Rapid Urbanization Area of China. *Journal of Agricultural Sciences*, *22*(2), 275–294. https://doi.org/10.1501/Tarimbil_0000001387

Marhaento, H., Booij, M. J., & Hoekstra, A. Y. (2018). Hydrological response to future land-use change and climate change in a tropical catchment. *Hydrological Sciences Journal*, *63*(9), 1368–1385. https://doi.org/10.1080/02626667.2018.1511054

Marwah, S. (2014). Analisis Perubahan Penggunaan Lahan dan Ketersediaan Sumberdaya Air di DAS Konaweha Propinsi Sulawesi Tenggara [Analysis of Changes in Land Use and Availability of Water Resources in the Konaweha Watershed, Southeast Sulawesi Province]. *Jurnal Agroteknos*, *4*(3), 208–218. https://www.neliti.com/publications/244543/analisis-perubahan-penggunaan-lahan-dan-ketersediaan-sumberdaya-air-di-das-konaw#cite

Mathewos, M., Lencha, S. M., & Tsegaye, M. (2022). Land Use and Land Cover Change Assessment and Future Predictions in the Matenchose Watershed, Rift Valley Basin, Using CA-Markov Simulation. *Land*, *11*(10), Article 1632. https://doi.org/10.3390/land11101632

Ministry of Environment and Forestry. (2022). *Penutupan Lahan Kawasan Hutan (A.1)* [Forest Land Cover Metadata (A.1)]. SIGAP KLHK. Retrieved July, 5, 2022 from https://www.webgis.menlhk.go.id.

Nathania, S., Fatimah, E., & Suharto, B. B. (2022). Efforts to Reduce River Water Discharge through Land Use Control (Case Study: Upstream Ciliwung Watershed, Indonesia). *Journal of Applied Geospatial Information*, *6*(2), 674–680. https://doi.org/10.30871/jagi.v6i2.4730

Piao, Y., Jeong, S., Park, S., & Lee, D. (2021). Analysis of Land Use and Land Cover Change Using Time-Series Data and Random Forest in North Korea. *Remote Sensing*, *13*(17), Article 3501. https://doi.org/10.3390/rs13173501

Rahmawaty, R., Rauf, A., Harahap, M. M., & Kurniawan, H. (2022). Land cover change impact analysis: an integration of remote sensing, GIS and DPSIR framework to deal with degraded land in Lepan Watershed, North Sumatra, Indonesia. *Biodiversitas*, *23*(6), 3000–3011. https://doi.org/10.13057/biodiv/d230627

Ramadhan, G. F., & Hidayati, I. N (2022). Prediction and Simulation of Land Use and Land Cover Changes Using Open Source QGIS. A Case Study of Purwokerto, Central Java, Indonesia. *Indonesian Journal of Geography*, *54*(3), 344–351. https://doi.org/10.22146/ijg.68702

Rakuasa, H., & Pakniany, Y. (2022). Spatial Dynamics of Land Cover Change in Ternate Tengah District, Ternate City, Indonesia. *Forum Geografi, 36*(2), 126–135. https://doi.org/10.23917/forgeo.v36i2.19978

Said, M., Hyandye, C., Komakech, H. C., Mjemah, I. C., & Munishi, L. K. (2021). Predicting land use/cover changes and its association to agricultural production on the slopes of Mount Kilimanjaro, Tanzania. *Annals of GIS*, *27*(2), 189–209. https://doi.org/10.1080/19475683.2020.1871406

Said, M., Hyandye, C., Mjemah, I. C., Komakech, H. C., & Munishi, L. K. (2021). Evaluation and Prediction of the Impacts of Land Cover Changes on Hydrological Processes in Data Constrained Southern Slopes of Kilimanjaro, Tanzania. *Earth*, *2*(2), 225–247. https://doi.org/10.3390/earth2020014

Sattari, M. T., Mirabbasi, R., Dolati, H., Shaker Sureh, F., & Ahmad, S. (2020). Investigating the Effect of Managing Scenarios of Flow Reduction and Increasing Irrigation Water Demand on Water Resources Allocation Using System Dynamics (Case Study: Zonouz Dam, Iran). *Journal of Tekirdag Agricultural Faculty*, *17*(3), 406–421. https://doi.org/10.33462/jotaf.703167

Sulawesi River Regional Office IV. (2022). *Konaweha Watershed Data for 2002-2022* [Hard copy data]. Sulawesi River Regional Office IV.

Tang, Y., Chen, F., Yang, W., Ding, Y., Wan, H., Sun, Z., & Jing, L. (2022). Elaborate Monitoring of Land-Cover Changes in Cultural Landscapes at Heritage Sites Using Very High-Resolution Remote-Sensing Images. *Sustainability*, *14*(3), Article 1319. https://doi.org/10.3390/su14031319

Taufik, T., Mukaddas, J., & Hasddin, H. (2021). Tingkat Perubahan Tutupan Lahan (Deforestasi) di DAS Tiworo Kabupaten Muna Barat [Land Cover Change Rate (Deforestation) in the Tiworo Watershed, West Muna Regency]. *Sang Pencerah: Jurnal Ilmiah Universitas Muhammadiyah Buton*, *7*(2), 260–269. https://doi.org/10.35326/pencerah.v7i2.1106

United Nations. (2018). *The Sustainable Development Goals Report 2018*. https://unstats.un.org/sdgs/files/report/2018/thesustainabledevelopmentgoalsreport2018-en.pdf

Wolde, Z., Wei, W., Likessa, D., Omari, R., & Ketema, H. (2021). Understanding the Impact of Land Use and Land Cover Change on Water–Energy–Food Nexus in the Gidabo Watershed, East African Rift Valley. *Natural Resources Research*, *30*(3), 2687–2702. https://doi.org/10.1007/s11053-021-09819-3

Yadav, S., Babel, M. S., Shrestha, S., & Deb, P. (2019). Land use impact on the water quality of large tropical river: Mun River Basin, Thailand. *Environmental Monitoring and Assessment*, *191*(10), Article 614. https://doi.org/10.1007/s10661-019-7779-3

Ye, J., Hu, Y., Zhen, L., Wang, H., & Zhang, Y. (2021). Analysis on Land-Use Change and Its Driving Mechanism in Xilingol, China, during 2000–2020 Using The Google Earth Engine. *Remote Sensing*, *13*(24), Article 5134. https://doi.org/10.3390/rs13245134

Yulianto, F., Maulana, T., & Khomarudin, M. R. (2019). Analysis of the dynamics of land use change and its prediction based on the integration of remotely sensed data and CA-Markov model, in the upstream Citarum Watershed, West Java, Indonesia. *International Journal of Digital Earth*, *12*(12), 1151–1176. https://doi.org/10.1080/17538947.2018.1497098

Yusuf, S. M., Murtilaksono, K., Hidayat, Y., & Suharnoto, Y. (2018). Analysis and prediction of land cover change in upstream Citarum watershed. *Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan, 8*(3), 365–375. https://doi.org/10.29244/jpsl.8.3.365-375

Zhai, J., Xiao, C., Feng, Z., & Liu, Y. (2022). Spatio-Temporal Patterns of Land-Use Changes and Conflicts between Cropland and Forest in the Mekong River Basin during 1990–2020. *Land*, *11*(6), Article 927. https://doi.org/10.3390/land11060927

Zulkarnain, Z., Halili, H., & Diara, L. (2015). Analisis Spasial Perubahan Tutupan Lahan Pada Wilayah Pertambangan – Studi Kasus di Areal Bekas Tambang PT. Bumi Konawe Abadi Kecamatan Motui Kabupaten Konawe Utara (Spatial Analysis of Changes in Land Cover in Mining Areas; Case Study in the Former Mine Area of PT. Bumi Konawe Abadi, Motui District, North Konawe Regency). *Jurnal Ecogreen*, *1*(2), 11–24. https://ojs.uho.ac.id/index.php/green/article/view/3893/2973