Comparison of water availability in 2015 and 2022 based on land cover in the Maros River Basin

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Abstract  Forest as one of permanent vegetation can have an impact either to increase or decrease the quality of a watershed due to the changes in land cover. Land use activities that are changing landscapes within a watershed can often affect water yield. This study aims to determine the availability of water in Maros watershed in 2015 and 2022 and to identify the sub-watershed experiencing changes in water availability. Data analysis in this study uses the SWAT (Soil and Water Assessment Tool) model. Input data used in the analysis are the 2015 land use map, 2022 land cover projected map (Markov model analysis), soil type map, and Digital Elevation Model (DEM) data. The results showed that land cover in 2015 and 2022 was projected to change. The number of settlement and rice fields area was increased, while the forest vegetation was decreased. The change in land cover will affect water availability. The result of the SWAT modeling analysis showed that the availability of water in Maros Watershed in 2015 was 1,303,169,370 m$^3$, and in 2022 was 1,322,495,380 m$^3$. The volume of water availability from 2015 to 2022 has increased by 19,326,010 m$^3$. The increase that occurred was influenced by the surface flow, which increased from 2015 to 2022. There are 38 sub-watershed, which have decreased water availability, 26 sub-watersheds in which the water availability was increased while one sub-watershed did not change at all.

1. Introduction
The Ministry of Public Works in 2006 stated that the availability of water in Indonesia was 15,500 m$^3$/capita/year, higher than the average level of world water availability, which was only 7,176 m$^3$/capita/year. Theoretically, Indonesia should not experience water availability problems [1]. In fact, Indonesia is always faced with a crucial problem related to water security. This is because the availability of clean water potential from each year tends to decrease due to the degradation of the carrying capacity of the upstream watershed, which because of uncontrolled forest damage [2]. Forest as one of the permanent vegetation can have an impact on the increase or decrease in the quality of a watershed due to changes in land cover.

Land cover change is different in land activity compare with the previous activity, both for commercial and industrial purposes [3]. Various human activities to meet their needs mostly rely on or
are on land. Land use activities that are changing landscape in a watershed area can often affect water yield [3]. Changes in the area of land cover affect the amount of water availability [4].

Along with the rapid development and progress of Makassar City, Makassar City faces several problems, such as clean water. This is due to high population growth, which causes a high level of clean water use as well. In addition, increasing urbanization and industrialization in Makassar City has a negative effect on water resources in general and groundwater in particular [5]. Makassar City does not have a water supply, to meet water needs the people of Makassar City supply clean water from other regions. One area that is a source of water is the Maros Regency, which is part of Maros Watershed.

Changes in land cover in 1996 and 2015 in Maros watershed, a change of function of forest land to non-forest. The impact of these activities is the occurrence of higher surface runoff fluctuation in the rainy season, and the water supply in the dry season is running low. The imbalance of the hydrological condition of the Maros watershed affects the level of water availability supplied by the Maros watershed to Makassar City. Based on the result of the analysis of the level of monthly water availability in Maros watershed, it is estimated that from the period 1987-1996 to 2004-2013, the level of availability decreased by 11.8% or as much as 71,663,459 mm [1]. The actual water availability condition describes a future water availability condition and describes the water availability crisis.

The conversion of forest land function into developed land and the need for water, especially raw water, is increasing in line with current population growth. Information on water availability in the rainy and dry seasons needs to be analyzed. This information is used as a basis for determining future water resource planning in Maros watershed. Based on this, it is necessary to conduct research related to "Comparison of Water Availability in 2015 with Projected Land Cover in 2022 in Maros Watershed".

2. Research method
This research focuses on analyzing the availability of water in Maros watershed in 2022 and identifying the sub-watershed that have experienced changes in water availability as a spatial reference in Maros watersheds management planning, such as rehabilitation, reforestation program, and other programs that support water availability in Maros watershed. The analysis includes as follow;

2.1. Determination of research location boundary
Determination of the location of the study was obtained from the watershed boundary issued by the relevant agencies based on SK.511 / MENHUT-V / 2011 concerning the determination of the watershed map. To set the watershed boundaries including these stages: (1) Extracting watershed boundaries, (2) Downloading river network maps in the Geospatial Information Agency (BIG) portal, (3) making extracted contour map from 30 m DEM Aster data with an interval of 10 m (4) change the map coordinate system to UTM (5) run topo to raster (6) delineate watershed boundaries.
2.2. **Data source**

Data collected in this study, including primary and secondary data. Primary data is obtained directly through the interpretation of satellite imagery to create a land cover map. The collection of land cover data in the field is done by adjusting the classification of land cover in the field with the result of the satellite imagery interpretation in a purposive based on accessibility. Secondary data include the general condition of the research location obtained from literature studies as well as other data related to the research. The secondary data includes the DAS Boundary Map, River Network Map, DEM 30 m Aster, 2015 Land Cover Map, Soil Type Map, Climate Data, and Projected Land Cover 2022.

2.3. **Data analysis**

2.3.1. **SWAT Data Input**

2.3.1.1 **Land Cover Data.** Maros watershed land cover data in 2015 was obtained by interpreting Landsat 8 Path 116 Row 63 imagery in 2015. The imagery was provided by the United States Geological Survey and can be downloaded on the website [http://earthexplorer.usgs.gov](http://earthexplorer.usgs.gov). The visual delineation method is used to determine land cover class based on patterns and characteristics (hue, color, and texture). Then the field check is conducted.

Field checking was conducted with the purpose of making corrections to the result of land cover classification. The coordinate point was determined by using purposive sampling, which is to choose a location that represents every category of land cover that exists. The determination of the coordinate point is carried out by considering the accessibility factor with a maximum distance from the access is 500 m from each chosen land cover.

To test the accuracy of image interpretation, an image accuracy test is performed. Accuracy is a comparison between data interpretation results with field conditions. Calculation of the accuracy of image interpretation is done with a confusion matrix table. In the confusion matrix, the data resulting from image interpretation and data from field checking results are arranged in a percentage comparison table. Overall accuracy calculation:

\[
OA = \frac{X}{N} \times 100\% 
\]

where:

\(OA\) = Overal Accuracy (Calculation of overall image interpretation accuracy)
X = Number of matrix diagonal values
N = Number of matrix samples

| A | B | C |
|---|---|---|
| X | Xn | XK + |
| B | | XKK |
| C | | |

Row Total: X + K
N

The result of the image interpretation that has fulfilled is then changed to the naming database for SWAT land cover. Whereas the projection for land cover in 2022 was obtained from the result of the Musdalifah study [7]. In order to be simulated using the SWAT model, the 2022 land cover naming database was changed to the SWAT model naming database. The classification of land cover naming for the SWAT model shown in Table 2 [8]

Table 2. Classification of Land Cover Naming for the SWAT Model

| No. | Land Cover                  | SWAT Classification                  | SWAT Code |
|-----|-----------------------------|--------------------------------------|-----------|
| 1   | Secondary Dryland Forest    | Forest-Mixed                         | FRST      |
| 2   | Secondary Mangrove Forest   | Wetlands-Forest                       | WETF      |
| 3   | Plantation Forest           | Forest-Evergreen                     | FRSE      |
| 4   | Dry Land Agriculture        | Agriculture Land- Generic            | AGRL      |
| 5   | Rice field                  | Rice                                 | RICE      |
| 6   | Shrubs                      | Range-Brush                          | RNGB      |
| 7   | Savanna                     | Pasture                              | PAST      |
| 8   | Pond                        | Water                                | WATR      |
| 9   | Settlement                  | Residential                          | URBN      |
| 10  | Water Body                  | Water                                | WATR      |
| 11  | Airport                      | Transportation                        | UTRN      |

2.3.1.2. Soil type data. Soil type data was obtained from the land system data of the Regional Physical Planning Program for Transmigration (RePPProt) National Survey and Mapping Coordinating Board in 1987. The soil data input needed in the SWAT model is soil type, soil physical, and chemical parameters. So as to meet the needs of the SWAT parameter input, an analysis is carried out to obtain the input parameter soil data. Approached Analysis used is to extract soil information from the RePPProt map combined with information from USDA Natural Resource Conservation Service Web Soil. The input parameters of the type of soil needed to run ArcSWAT, shown in Table 3 [8]

Table 3. Parameter of SWAT Soil Types

| No. | Soil Parameters          | SWAT Code |
|-----|--------------------------|-----------|
| 1   | Number of Soil layer     | NLAYERS   |
| 2   | Soil Hydrology Group     | HYDGRP    |
| 3   | Plant Root Depth (mm)    | SOL_ZMX   |
| 4   | Land Porosity (fraction) | ANION_EXCL|
| 5   | Land Crack Volume (m3 / m3) | SOL_CRK  |
| 6   | Texture                  | TEXTURE   |
| 7   | Land Depth (mm)          | SOL_Z     |
| 8   | Bulk Density (g / cm3)   | SOL_BD    |
5

| No. | Soil Parameters                                         | SWAT Code |
|-----|--------------------------------------------------------|-----------|
| 9   | Available water capacity (mm / mm)                     | SOL_AWC  |
| 10  | Organic C content (%)                                  | SOL_CBN  |
| 11  | Saturated Hydraulic Conductivity (mm / day)            | SOL_K    |
| 12  | Clay Percentage (%)                                    | CLAY     |
| 13  | Dust Percentage (%)                                    | SILT     |
| 14  | Sand Percentage (%)                                    | SAND     |
| 15  | Percentage of Surface Stone (%)                        | ROCK     |
| 16  | Albedo Land (fraction)                                 | SOL_ALB  |
| 17  | Land Erodibility                                       | USLE_K   |
| 18  | Electrical Conductivity (ds / m)                        | SOL_EC   |
| 19  | Calcium carbonate (%)                                  | SOL_CAL  |
| 20  | pH                                                     | SOL_PH   |

a. **Slope data.** The slope data is obtained by running the ArcSWAT program. The slope class classification used is 0-8%, 8-15%, 15-25%, 25-40%, and > 40%.

b. **Climate data.** Climate data is obtained from related global data called Global Weather. Climate data can be obtained through the website [http://globalweather.tamu.edu/](http://globalweather.tamu.edu/). The climate data needed are rainfall, temperature, solar radiation, air humidity, and wind speed data, which are daily calculations from 2004-2013. The rainfall station numbers in the Maros watershed are 481194, 481197, 521194, 521197, and 521200.

2.3.2. **Formation Hydrological Response Unit.** Hydrological Response Unit or HRU is the smallest unit in the scale of analysis conducted on SWAT modeling. HRU formation is done by overlaying land cover map, soil types map, and slope data. Each HRU that is formed contains specific information about the land, which includes land cover, soil type, and slope. Land cover data and soil types used in the HRU analysis are in the ESRI raster format, while the slope class classification is derived from the DEM dataset used to delineate watershed boundaries. The dataset used uses the same projection system [9].

2.3.3. **Combining HRU with Climate Data.** The merger of HRU and climate data is done after one of each analysis is formed. At this stage, a Weather Generator Data (WGN) file, which is pre-arranged, is called. Rainfall data series (mm), air temperature (°C), solar radiation (MJ / m² / day), air humidity (%), and wind speed (m / s). The data is collected into PCP files for rainfall, TMP for temperature, SOLAR for solar radiation, RH for humidity, and WIND for wind speed with the extension .txt. The simulation process is run on a monthly basis.

2.3.4. **Simulation of the Soil and Water Assessment Tool Model.** SWAT model simulation is done after the merging process of HRU with climate data was completed. The simulation process is run on a monthly basis, with ten years of simulated data. The SWAT model can be run in ArcSWAT with the SWAT Simulation menu with the condition that the Watershed Delineation, HRU Analysis, and Write Input Tables stages are completed properly. After the simulation stage has been conducted using the Run SWAT process, the next step is to display the output result of the simulation. The process is conducted by using the Read SWAT Output sub-menu. The output from the simulation is then stored for the next analysis.
2.3.5. **Water availability.** At this stage, the simulation output of the SWAT model is defined. In the SWAT model, water availability is termed the water yield (mm) obtained in each subwatershed. Water yield is obtained from the calculation using the following formula.

\[
\text{WYLD} = \text{SURQ} + \text{LATQ} + \text{GWQ} - \text{TLOSS} - \text{pond abstractions}
\]

where:
- \(\text{WYLD}\) = The amount of effective water available in a watershed (mm)
- \(\text{SURQ}\) = Amount of surface runoff reaching the main river (mm)
- \(\text{LATQ}\) = The amount of water flowing laterally beneath the surface which contributes to river discharge (mm)
- \(\text{GWQ}\) = The amount of water flowing in *aquifer* who contributed towards river discharge (mm)
- \(\text{TLOSS}\) = Total water loss to the *aquifer* (mm)

2.3.6. **Water Supply Level Mapping.** After the output of water availability is defined, the next step is to create a range of water availability classes to determine the level of water availability in the region. The range of water availability class is obtained from the class interval formula by subtracting the highest and the lowest value then dividing according to the desired class so that the interval value is obtained. The interval classes used are low, medium, and high. After obtaining interval class data, then map the level of water availability using a geographic information system.

2.3.7. **Comparison of Level of Water Availability in 2015 and in 2022.** Comparison of water availability in 2015 and 2022 is made by using overlay techniques in geographic information systems. The results show that the difference in water availability numbers in 2015 and 2022 to find out where there has been a decrease or increase in water availability.

### 3. Results and Discussion

#### 3.1. Land Cover

Land cover in SWAT input using two types of land cover data, which are 2015 land cover and projected land cover in 2022. Both of these data are used to see an increase or decrease in water availability.

#### 3.1.1. Land Cover in 2015

Land cover was obtained from the analysis of the Landsat Image 8 interpretation and the result of the Maros watershed field check. There are 11 types of land cover, which are dominated by dryland agriculture and rice fields. So that land cover data can be used in the SWAT model, the naming of the land cover must be adjusted to the classification of the SWAT model naming. The result of the SWAT classification, area, and percentage of the area shown in Table 4.

| No. | Land Cover          | SWAT Classification     | SWAT Code | Area (ha) | Percentage (%) |
|-----|---------------------|-------------------------|-----------|-----------|----------------|
| 1   | Airport Transportation          | UTRN                  | 225.57    | .34       |
| 2   | Secondary Mangrove Forest Wetlands-Forest | WETF | 5.75    | 0.01     |
| 3   | Secondary Dryland Forest Forest-Mixed | FRST | 12,283.72 | 18.5    |
| 4   | Plantation Forest Forest-Evergreen Residential | FRSE, URB | 1,916.49 | 2.89      |
| 5   | Settlement Agriculture Land-Genric | AGRL | 1,032.07 | 1.55     |
| 6   | Dry Land Agriculture Pasture | PAST | 29,063.89 | 43.77   |

| 7   | Savanna Pasture | PAST | 276.56 | 0.42 |

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Land cover in Maros watershed is dominated by dryland agriculture with the area of 29,063.89 ha (43.77%) and rice field with an area of 15,581.12 ha (23.47%) of Maros watershed, while the forest vegetation is only 21.39% of Maros watershed which consist of secondary mangrove forest with an area of 5.75 ha (0.01%), secondary dryland forest with an area of 12,283.72 ha (18.50%) and plantation forest with an area of 1,916.49 ha (2.89%). Map of the distribution of land cover in 2015, shown in Figure 2.

The result of the Landsat 8 image interpretation in 2015 of the land cover class was tested for image interpretation accuracy. An accuracy test is performed to determine the accuracy of the interpretation of the image that has been classified.

![Figure 2. Land Cover Map in 2015](image)

The result of the confusion matrix field checkpoints for each land cover class, it is known that there are 100 sample points (N). The number of points that proved to be correct in the field was 89 points (X). According to these results, an accuracy test of overall accuracy was made to find out the percentage of a confidence level for each land cover class in Maros watershed. Overall accuracy shows the confidence level of an overall interpretation of Landsat imagery. By looking at the diversity of land cover classes in Maros watershed and the overall accuracy calculation result of 89%, this shows that the interpretation of Landsat imagery is acceptable. This is in line with the opinion of Lillesand and Kiefer, which states that the interpretation of satellite imagery data in various areas with 85% accuracy is acceptable [10].

### 3.1.2. Land Cover Projection in 2022

The projected land cover in 2022 is the result of Musdalifah research obtained by using markov modeling on GIS software [7]. According to the result of land cover projection, 11 land cover classifications are obtained in Maros watershed. So that the data on land cover projection can be used in the SWAT model, the naming of land cover projection must be adjusted to the classification of the SWAT model naming. The result of the SWAT model land cover projection classification shown in Table 5.
Table 5. Projected Land Cover in 2022

| No. | Land Cover               | SWAT Classification    | SWAT Code | Area (Ha) | Percentage (%) |
|-----|--------------------------|------------------------|-----------|-----------|----------------|
| 1   | Airport                  | Transportation         | UTRN      | 307.73    | 0.46           |
| 2   | Secondary Mangrove Forest| Wetland-Forest         | WETF      | 28.94     | 0.04           |
| 3   | Secondary Dryland Forest | Forest-Mixed           | FRST      | 10,521.31 | 15.85          |
| 4   | Plantation Forest        | Forest-                | FRSE      | 2,378.60  | 3.58           |
| 5   | Settlement               | Residential            | URBN      | 1,699.20  | 2.56           |
| 6   | Dry Land Agriculture     | Agriculture            | AGRL      | 28,882.12 | 43.50          |
| 7   | Savanna                  | Pasture                | PAST      | 214.02    | 0.32           |
| 8   | Rice field               | Rice                   | RICE      | 16,850.54 | 25.38          |
| 9   | Shrub                    | Range-Brush            | RRGB      | 1,817.52  | 2.74           |
| 10  | Pond                     | Water                  | WATR      | 3,000.54  | 4.52           |
| 11  | Water Body               | Water                  | WATR      | 698.70    | 1.05           |
|     | **Total**                | **66,399.21**          |           | **100.00**|                |

Table 5 shows that the result of projected land cover in 2022 in Maros watershed is dominated by dryland agriculture of 28,882.12 ha (43.50%) of the Maros watershed area. Map of projection for land cover in 2022, shown in Figure 3.

3.1.3. Comparison of Land Cover in 2015 with Projected Land Cover in 2022. Figure 4 shows that land cover in Maros watershed is projected to be changed in several types of land cover. This is marked by a change in the function of vegetation land cover to become non-vegetation. The land cover in 2015, secondary dryland forest was 18.50% (12,283.72 ha) out of the watershed area, but land cover in 2022 it was projected to be reduced by 15.85% (10,521.31 ha) which means that it decreases 2.65% of the total area. Reduction of secondary dryland forest because part of the area was converted to plantation forest, rice field, and settlement. While the settlement is projected to increase, from
1,032.07 ha (1.55%) in 2015 to 1,699.20 ha (3.58%) out of the total watershed area in 2022, the increase of settlement is projected to occur because of the increase in the population. It is not only the settlement that has increased but also the rice field due to the impact of the increasing population.

![Figure 4. Comparison of Land Cover in 2015 and 2022](image)

3.2. Water availability

The value of water availability is obtained from two types of land cover; those are land cover in 2015 and the projected land cover in 2022, which results in simulation by using the SWAT model. The model analysis uses the Hydrologic Response Unit (HRU) analysis, where the parameter used are spatial land cover data (two types of land cover data), soil type data, slope data, and climate data.

3.2.1. Water availability in 2015. Watershed makes a major contribution to the availability of water. The high land-use change in a watershed impacted to the hydrological system imbalance of the watershed. According to the watershed hydrological condition simulation in Maros watershed by using the SWAT model, the water availability of land cover in 2015 was obtained. The spatial visualization of the level of water availability in 2015, shown in Figure 5. It shows that the class of water availability in 2015 in Maros watershed are classified into 3 classes, those are low class (1,803,140.80 - 2,108,198.43 m³), moderate (2,109,198.43 - 2,414,256.07 m³) and high (2,415,256.07 - 2,721,313.70 m³). High water availability class is in sub-watershed 51, 52, and 62. The moderate water availability class is in sub-watersheds 4 and 8, while the low water availability class is in all sub-watersheds (4, 8, 51, 52, and 62).

The value of water availability shown in Figure 6. It shows that in the dry season, the lowest water availability is in August, and in the rainy season, the highest water availability is in December.
3.2.2. **Water availability in 2022.** According to the simulation result of the watershed hydrological condition in Maros watershed using the SWAT model, the water availability of projected land cover in 2022 was obtained. The spatial visualization of water availability level in 2022, shown in Figure 7. It shows that the class of water availability in 2022 in Maros watershed is classified into 3 classes, those are low class (1,803,140.80-2,108,198.43 m$^3$), moderate (2,109,198.43-2,414,256.07 m$^3$) and high (2,415,256.07-2,721,313.70 m$^3$). High water availability class is in sub-watershed 51, 52, and 62. The moderate water availability class is in sub-watersheds 4 and 8, while the low water availability class is in all sub-watersheds (4, 8, 51, 52, and 62).
Figure 7. Map of Water Availability Level in 2022

Figure 8. Number of Monthly Availability in 2022

Figure 8 shows that in the dry season, the lowest water availability was in August, and in the rainy season, the highest water availability was in January.

3.2.3. Comparison of Water Availability in 2015 and 2022

The simulation result of a watershed hydrological condition in Maros watershed by using the SWAT model, based on 2015 land cover and projected land cover in 2022, the number of water availability in 2015 was 1,303,169,370 m$^3$ and in 2022 was 1,322,495,380 m$^3$. Visually, the comparison of water availability in 2015 and 2022, shown in Figure 9.

Figure 9 shows that there are 38 sub-watersheds that have decreased water availability. There are 26 sub-watersheds that have increased water availability and one sub-watershed that has not changed. Change in water availability condition that occurs in each sub-watershed gives an illustration of the influence of change in land cover on water availability.
Figure 9. Comparison of Water Availability in 2015 and in 2022 in Each Sub Watershed

Water yield is the availability of water, which is influenced by the accumulation of runoff, lateral flow, and baseflow or ground flow. The condition of water availability based on the comparison of land cover in 2015 and 2022 shows that the sub-watershed with the highest change value is in sub-watershed 8, which is dominated by a rice field in 2015 and changed to settlement as it projected to be in 2022. This condition impacted the increase of surface runoff, while lateral flow and groundwater are decreasing, which affect water availability in sub-watershed is surplus. The sub-watershed with the lowest change value is in sub-watershed 13, which is dominated by dry land agriculture mixed with shrub in 2015 and in 2022 is projected to become rice field.

Water availability is the accumulation of runoff, lateral flow, and groundwater/base flow. Figure 10 shows the runoff, lateral flow, and groundwater conditions in 2015 and 2022.

Figure 10. Runoff, Lateral Flow and Ground Water in 2015 and 2022 for each Sub-watershed

Runoff is a watershed response to rainfall due to differences in land cover. As shown in Figure 10, an increase in surface runoff is caused by changes in land cover that are projected to be in 2022, which are the reduction in forest area and an increase of settlement and rice field. In line with Pratama & Yuwono (2016), which states that an increase in the settlement area causes the surface flow coefficient to increase. And Nursaputra (2014) states that the increasing proportion of forest area in a
watershed causes the surface runoff is decreasing, otherwise the decreasing of forest proportion causes surface runoff is increased.

In Figure 10, it can be seen that sub-watershed 49 has the highest runoff value in 2015 and 2022. This is due to the land cover that dominates is dryland agriculture mixed with shrub increasing in the area. The increase of this land cover causes the increase of surface runoff, in line with the statement of Pratama & Yuwono (2016), an increase in the area of mixed dryland agriculture causes surface runoff to increase.

Changes in lateral flow also affect water availability. In Figure 10, it can be seen that sub-watershed 62 has the highest lateral flow values in 2015 and 2022. This is due to the condition of land cover in the sub-watershed. This sub-watershed was dominated by plantation forest in 2015, and the area will be increased in 2022 as it projected.

Changes in groundwater flow also affect water availability. In Figure 10, it can be seen that sub-watershed 2 has the highest groundwater values in 2015 and 2022. This is due to the condition of land cover in sub-watershed. Sub-das 2 was dominated by ponds in 2015, and it was projected that would still be dominated by ponds but reduce in 2022.

4. Conclusion

Based on the research objectives, it can be concluded that the simulation of water availability in Maros watershed is 1,303,169,370 m$^3$ in 2015 and 1,322,495,380 m$^3$ in 2022. The number of water availability from 2015 to 2022 has increased by 19,326,010 m$^3$. The increase that occurred is influenced by the surface flow, which increased from 2015 to 2022. There are 38 sub-watersheds that have decreased water availability, 26 sub-watersheds that have increased water availability, and one sub-watershed that did not experience any changes in water availability.

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