Teaching & Learning
Step-by-Step Guide:

Modeling the Future Land Use Change using MOLUSCE

Amila Jayasinghe
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Samith Madusanka

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Publisher

University of Moratuwa

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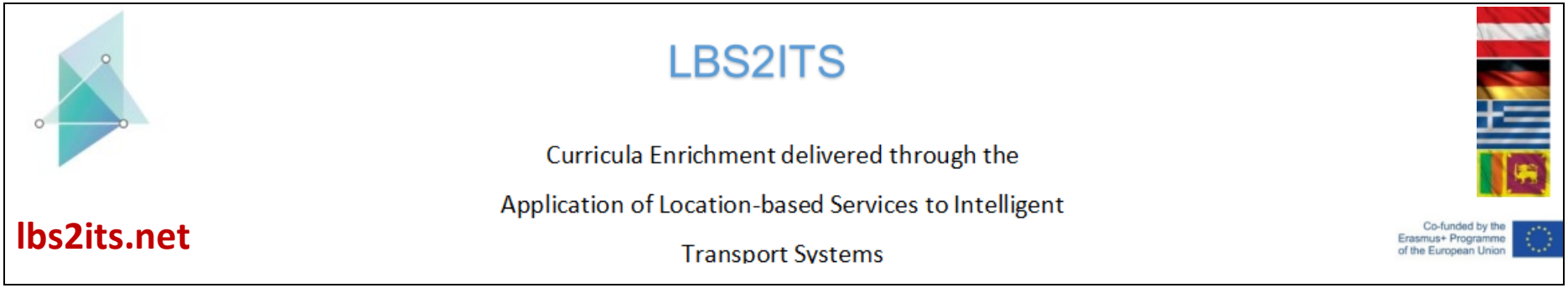

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PREFACE

This book serves as an open educational resource for both undergraduate and postgraduate degree programs, offering a detailed, step-by-step guide to modeling future land use change using the MOLUSCE plugin in QGIS. Designed to bridge the gap between theoretical knowledge and practical application, this guide is meticulously crafted to meet the needs of students, educators, and practitioners alike.

Within the book, readers will find comprehensive instructions on utilizing advanced algorithms such as Artificial Neural Networks (ANN), Logistic Regression (LR), and Weight of Evidence (WoE) to analyze and predict future land use changes. The guide provides detailed processes for ingesting raster data representing historical land use patterns and pertinent explanatory variables, training predictive models, and simulating future land use scenarios.

The book not only enhances learning in academic settings by providing real-world applications and case studies but also equips industry professionals with the skills necessary to conduct advanced spatial analysis and contribute meaningful insights in their fields. By understanding and managing land use dynamics, users can anticipate and plan for changes, facilitating informed decision-making in areas such as urban planning, natural resource management, and environmental conservation.

Whether you are a student aiming to master land use modeling and geographic information systems, a teacher looking for robust educational tools, or a practitioner in need of refining your technical expertise, this book offers invaluable guidance and support. It ensures that users at all levels gain proficiency in leveraging modern technologies to explore and solve geographic challenges effectively, empowering proactive planning and management of land resources for resilient and sustainable landscapes.

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CHAPTER 1: INTRODUCTION

1.1 Modeling the Future Land Use Change using MOLUSCE

MOLUSCE (Modules for Land Use Change Simulations) is a powerful plugin designed to analyze and predict future land use changes within specific regions. Utilizing advanced algorithms such as Artificial Neural Networks (ANN), Logistic Regression (LR), and Weight of Evidence (WoE), MOLUSCE integrates various spatial and non-spatial factors to simulate land use dynamics over time. By ingesting raster data representing historical land use patterns and pertinent explanatory variables, MOLUSCE trains predictive models to forecast future land use scenarios.

This modeling approach offers several benefits for understanding and managing land use change. Firstly, MOLUSCE provides valuable insights into the potential impacts of various socio-economic, environmental, and policy factors on land use dynamics. By simulating future scenarios, allows stakeholders to anticipate and plan for changes in land use patterns, facilitating informed decision-making in areas such as urban planning, natural resource management, and environmental conservation. Additionally, MOLUSCE enables the assessment of different land management strategies and policy interventions, helping to identify optimal pathways for sustainable land use development.

MOLUSCE empowers users to explore and visualize future land use changes, enabling proactive planning and management of land resources for resilient and sustainable landscapes.

1.2 Required Equipment/s, Software/s, and Inputs

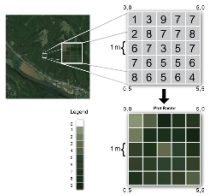
<table>
<tr><th>Equipment/s</th><th>Software/s</th><th>Inputs</th></tr>
<tr>
<td> 
Computer

• A computer with sufficient processing power and memory is necessary to run QGIS and MOLUSCE efficiently, especially when dealing with large datasets or complex analyses.

• There are no strict formal system requirements.

• It is recommended to have a computer with modern specifications to ensure smooth performance.</td>
<td> 
QGIS Desktop 3.22.7
• QGIS 3.0 or later can be used for data preparation works

 
QGIS Desktop 2.18.15
• This version of QGIS needs to be installed to use the MOLUSCE plugin.
• Users can download and install the plugin from the QGIS Plugin Repository here.

QGIS Platform Overview
• Type: Open-source
• Installation: Available for Windows, macOS, Linux</td>
<td> 
Raster Data
• Users require raster data representing historical land use patterns and explanatory variables (such as socio-economic factors, and environmental variables) relevant to the study area.

• These raster datasets can be obtained from various sources, including remote sensing data, governmental agencies, or research institutions.

• In the absence of such raster data sets, it is necessary to prepare those raster data sets through QGIS software, using the data as needed.</td>
</tr>
</table>

Table 1 -Required Items for Study

1.3 Final Result of the Modeling

Our modeling process using MOLUSCE has provided a clear picture of what Dambulla's landscape could look like in 2035. We used data from 2005 and 2020 to predict how land use will change in the future. By looking at various spatial and non-spatial factors such as environmentally sensitive areas, land use efficiency of the area, accessibility, access to basic services, and population density, we have made some strategic assumptions about how the land in the Dambulla region will be used in the coming years.

The results show us where things might stay the same and where big changes could happen. This helps us understand how our cities might grow, how agricultural activities might change, and how we can protect our environment better. By knowing what could happen, we can make better plans for the future, ensuring our landscapes are healthy and sustainable for years to come.

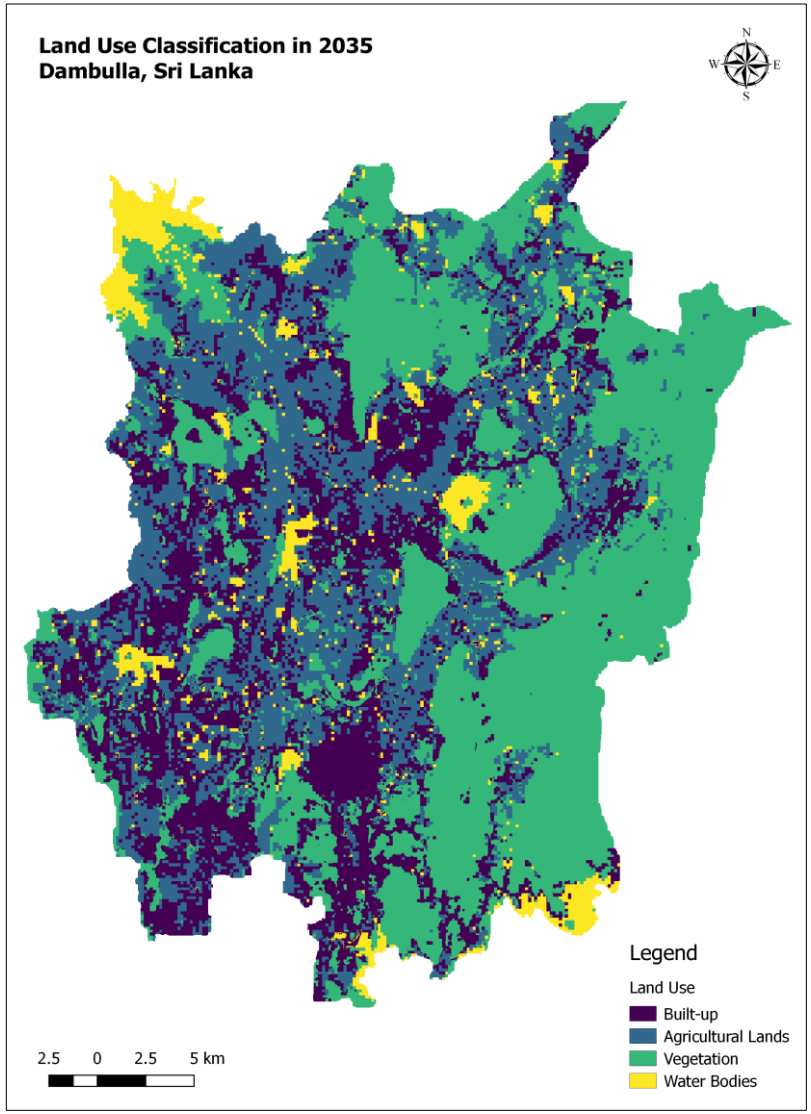


Figure 1 -Final Result of the Modeling

1.4 Data Preparation and Modeling Process

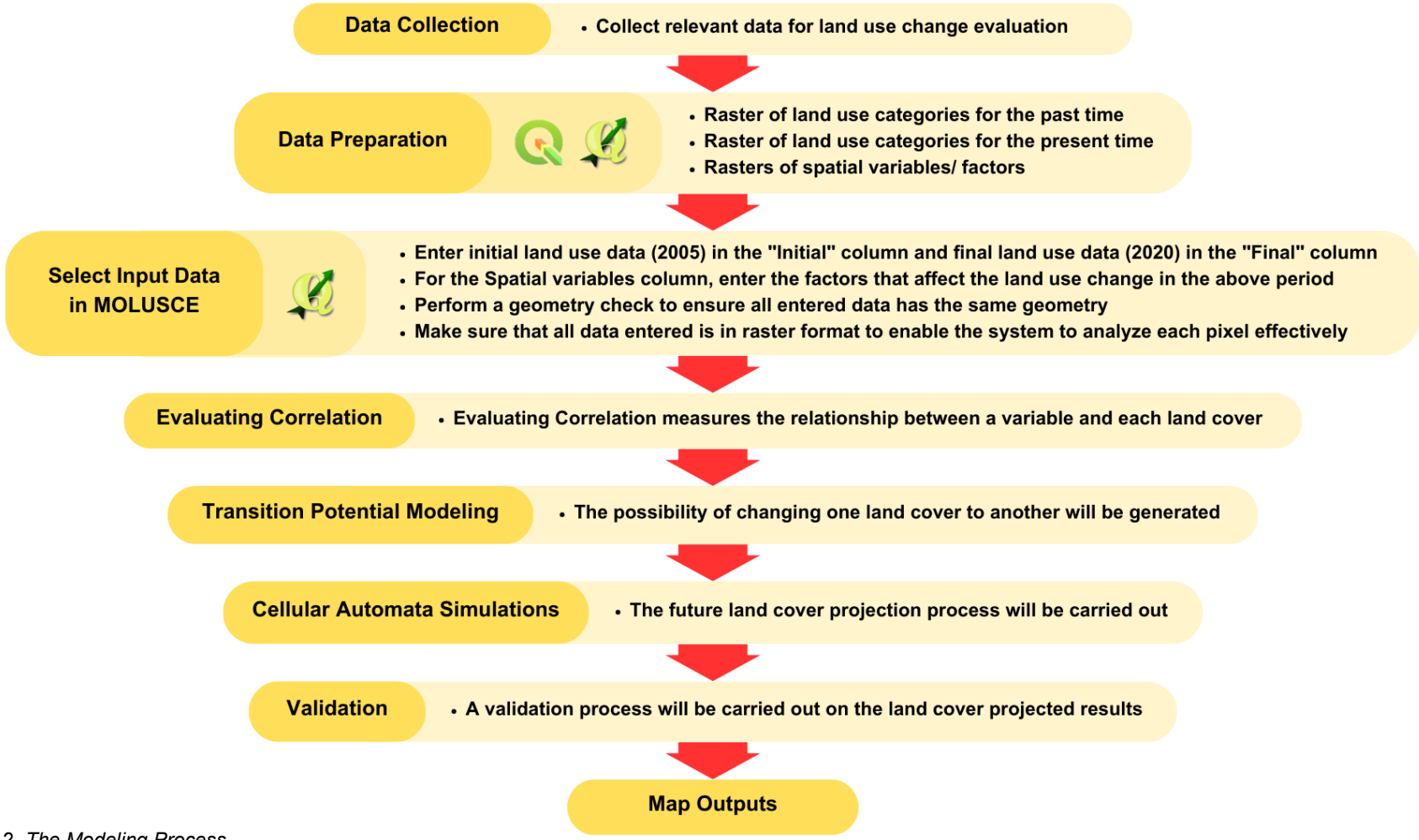


Figure 2 -The Modeling Process.

CHAPTER 2: DATA PREPARATION

Example Study Area

For this exercise, the Dambulla Regional area has been selected as the example study area. This is one of the major cities according to the National Physical Plan for 2050. Greater Dambulla Regional Boundary was introduced under this National Physical Plan of Sri Lanka, and it is to be used in this exercise.

Data Collection

By conducting a field visit in the Dambulla area, we identified its special characteristics. One of the special things that we focused on while doing the study was how the future land use pattern could be. Accordingly, we studied a considerable amount of past land use patterns and current land use patterns in this area. After collecting a certain amount of data with the help of local residents, we engaged in further studies with the help of local-level institutions and officials.

Additionally, we obtained some pre-processed datasets from government agencies such as the Urban Development Authority, Sri Lanka Mahaweli Authority, and the National Building Research Organization.

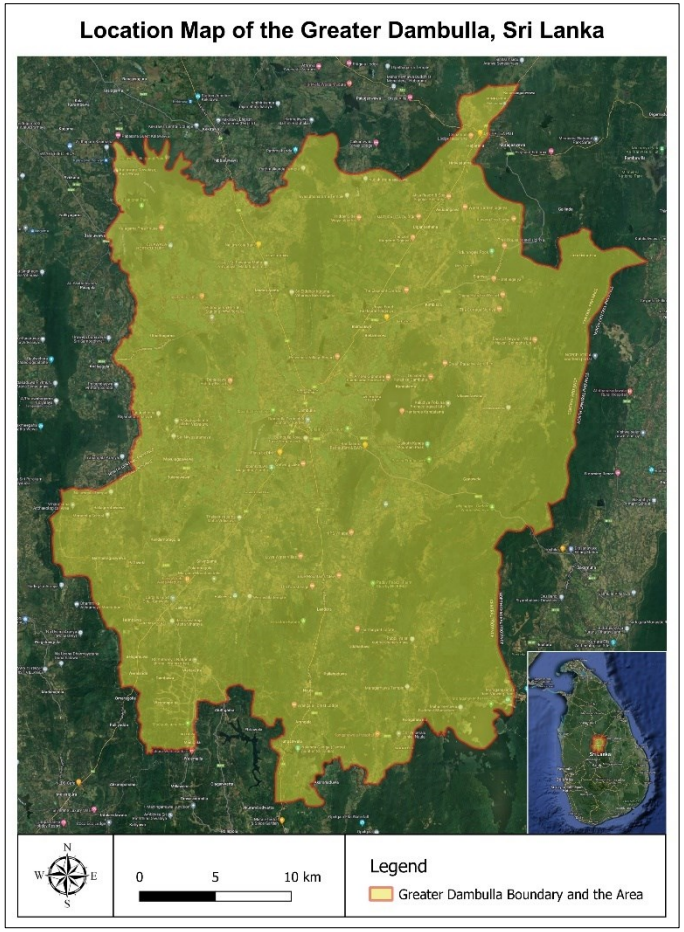


Figure 3 -The Study Area

2.1 Preparation of the Land Use Layers

To model the future land use change of a particular area using MOLUSCE, it is necessary to select a period and prepare relevant land use raster layers. These land use layers must be classified under certain major land uses. A high count of land use categories may cause errors while using MOLUSCE. In this exercise, the period considered here is from **2005 to 2020**, to predict the future land use change, and we used the classified land use layers for the years 2005 and 2020 separately. **Both the layers should have the same land use categories**. However, there is a practical possibility that one or more land use categories that did not exist in 2005 will be added by 2020.

In this situation, we cannot see that kind of scenario and the **Built-up areas, agricultural lands, vegetation layers, and water bodies** are the categories that are included in these layers that we have used.

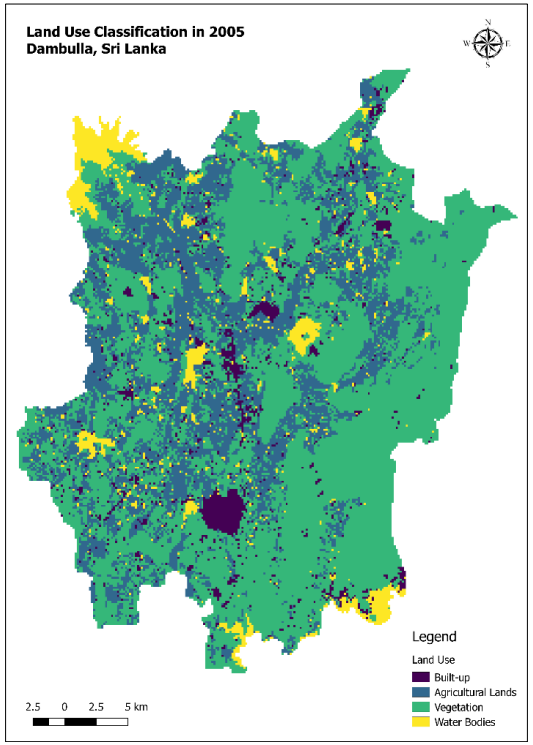


Figure 5 -Land use layer for the year 2005

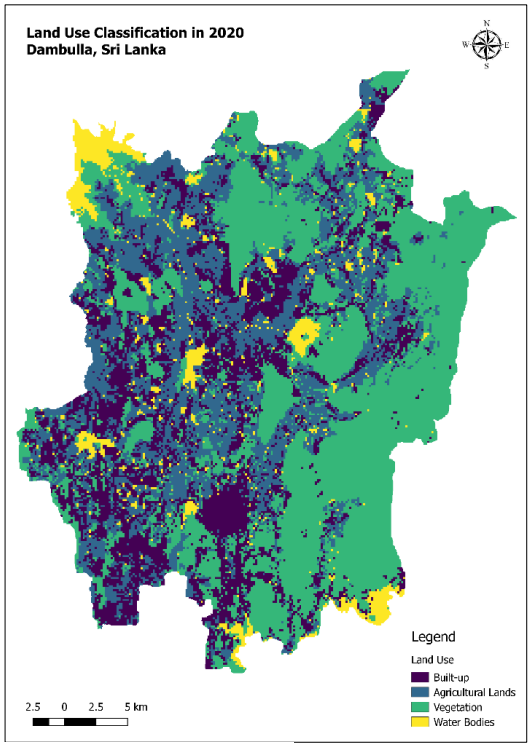


Figure 4 - Land use layer for the year 2020

Looking at the preparation of these two layers, the vector layers should be prepared first. Here we were able to obtain two pre-processed vector layers for the years 2005 and 2020 through their associated government agencies. If you are trying to make a land use prediction for an area like this, first find out if the area has pre-processed land use vector layers. Once you have gotten them, you can present the land use categories as needed through tasks such as updating their attribute tables.

The standard categorization of land uses can be shown as follows. If you are looking to do a detailed land use classification, Level 3 categorization is best for that. When it comes to Level 2, land uses are quite compact, and a collection of several land uses mentioned in Level 3 is included here in one category.

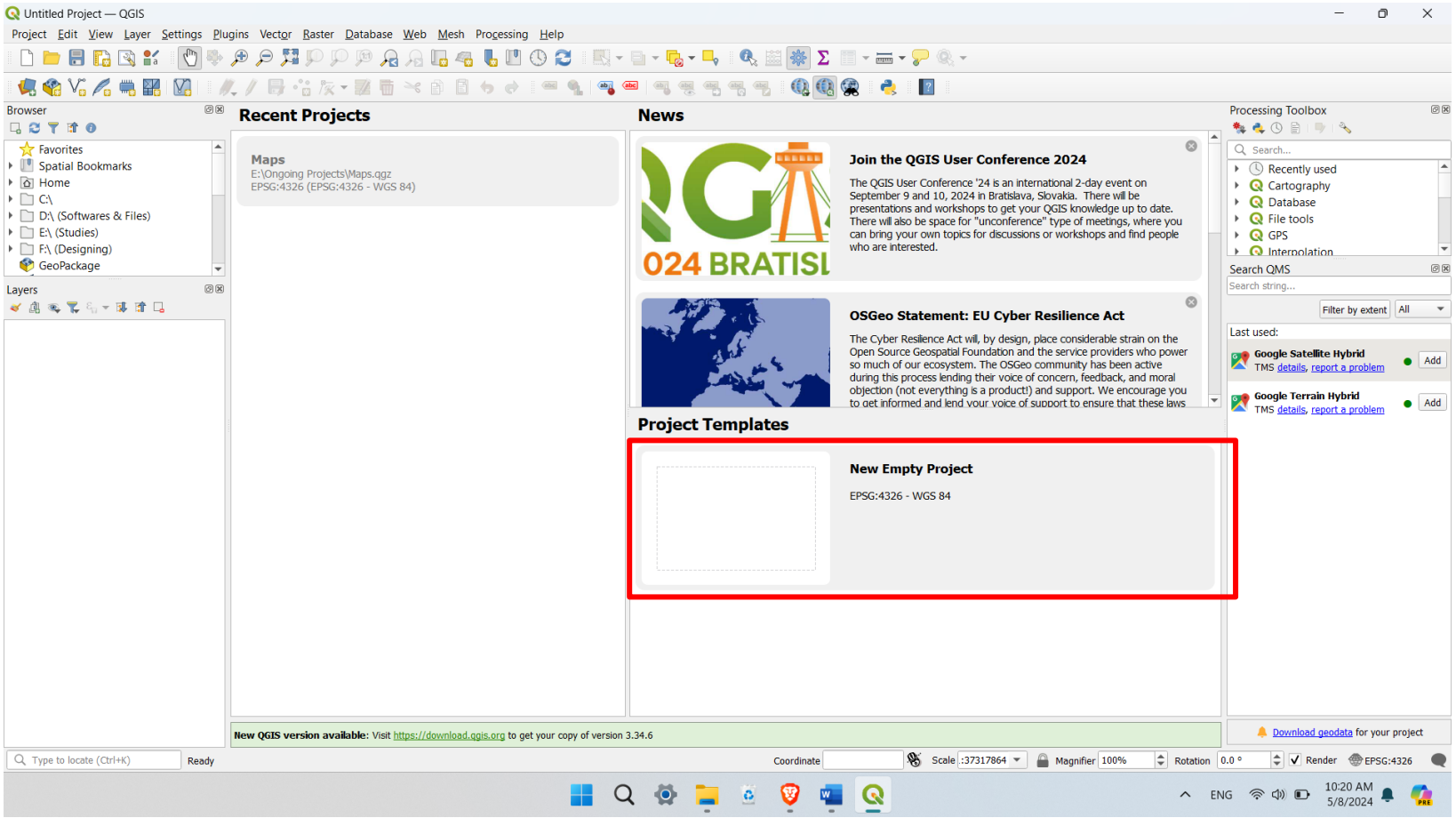
Level 1	Level 2	Level 3	
Build up Non-built-up	Business Commercial Education Government (Institutional) Health Industries/Distribution Open Land Other Residential Roads Transport Wetland	Airport Animal Clinics Bakery / Spa / Saloon/laundry / Shops and Houses Bank Bare Land (Land Sale / Non-Use Land / Etc.) Borrow Pits Bus Depot Bus Stands Cemetery Child Education Centers / Child Day Care Centers Church Condominium Scheme Conference & Exhibition Centers Construction Office & Yards Construction Site Corporations Court Houses Departments / Boards / Authorities Elderly Homes Embassy Financial Support Institution / Insurance Company Fuel Stations Garments General Hospital (Large Size Hospital)	Government Quarters Health Care Centers Hostels & Domes Hotel & Motel Hotel with More than 100 Rooms Housing Scheme More than 10 Houses Housing Scheme More than 100 Houses Individual Private Houses / Dwelling Houses International School / Private School Kovil Lakes Logistics and Distribution Centers Low-Income Houses Manufacturing Plants Market Marshy Medium Size Hospitals (District/Military Hospitals) Metal Quarry Military Admin Office Ministries Mosque Motor Vehicle Yard Museum Library

Table 2 – Standard Land Use Categorization

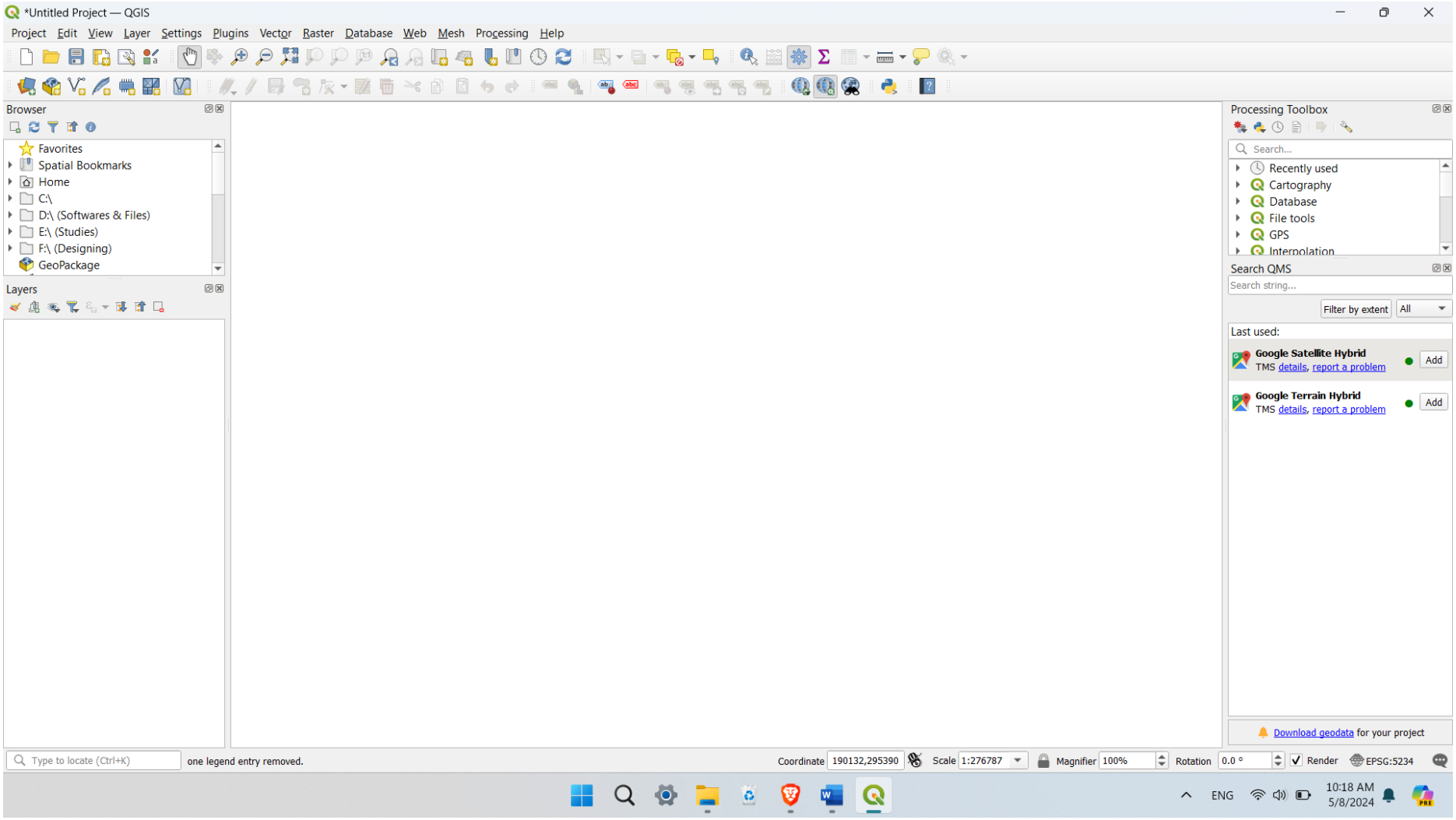
Regarding the Dambulla area, we mainly identified 4 land use categories. This can be expressed as a level 2 type of categorization because many types of land uses are shown in this one category here. For this categorization of the layer, first, we open the 2020 land use vector layer from the 2005 and 2020 land use layers through the QGIS 3.22.7 version. You can use any version of QGIS for this.

Step 01 –

1.1 Open the QGIS on your computer and click on "**New Empty Project**".



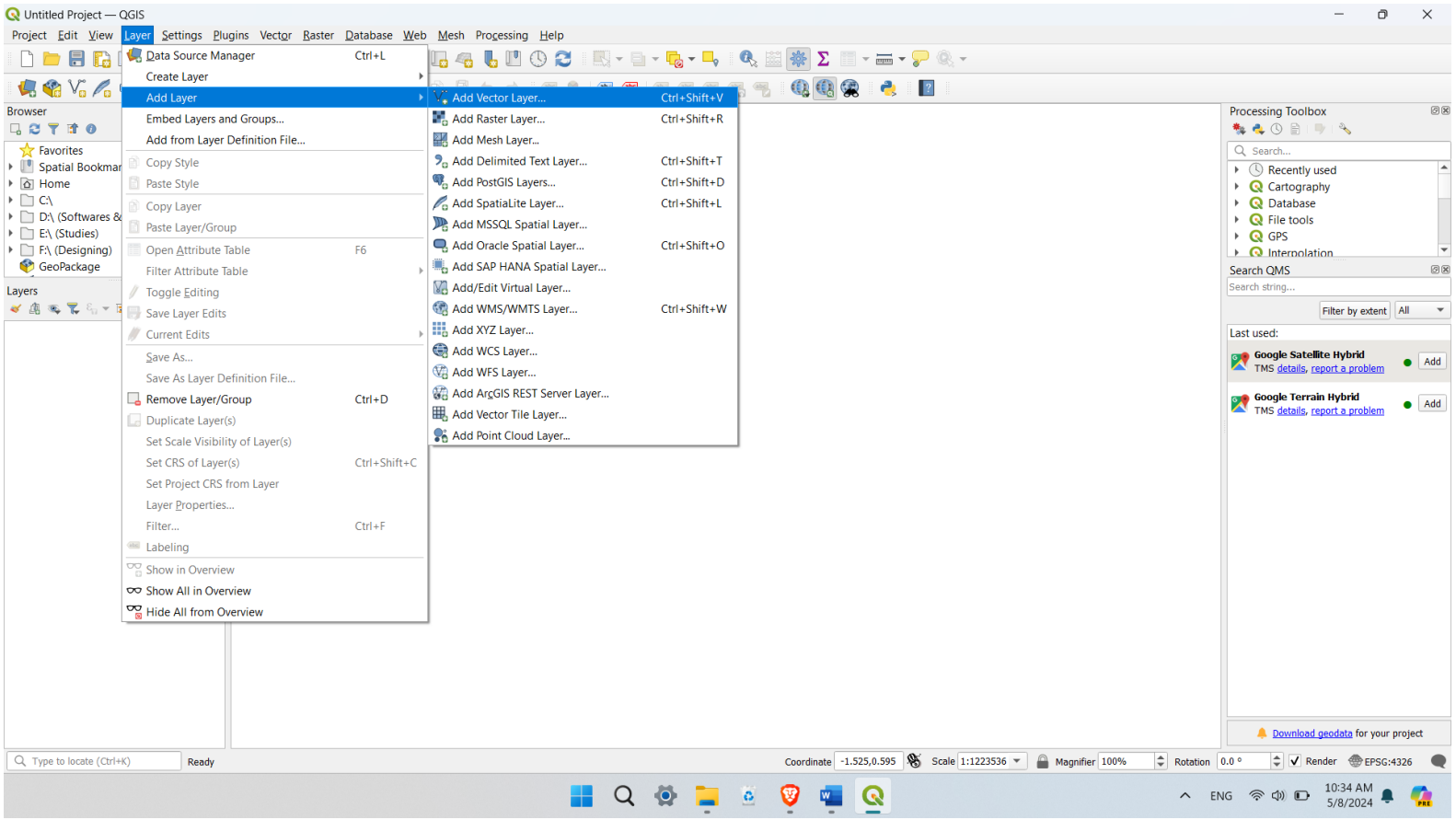
1.2 Then the workspace will be shown as follows on your screen. Next, we have to import the relevant vector layer.



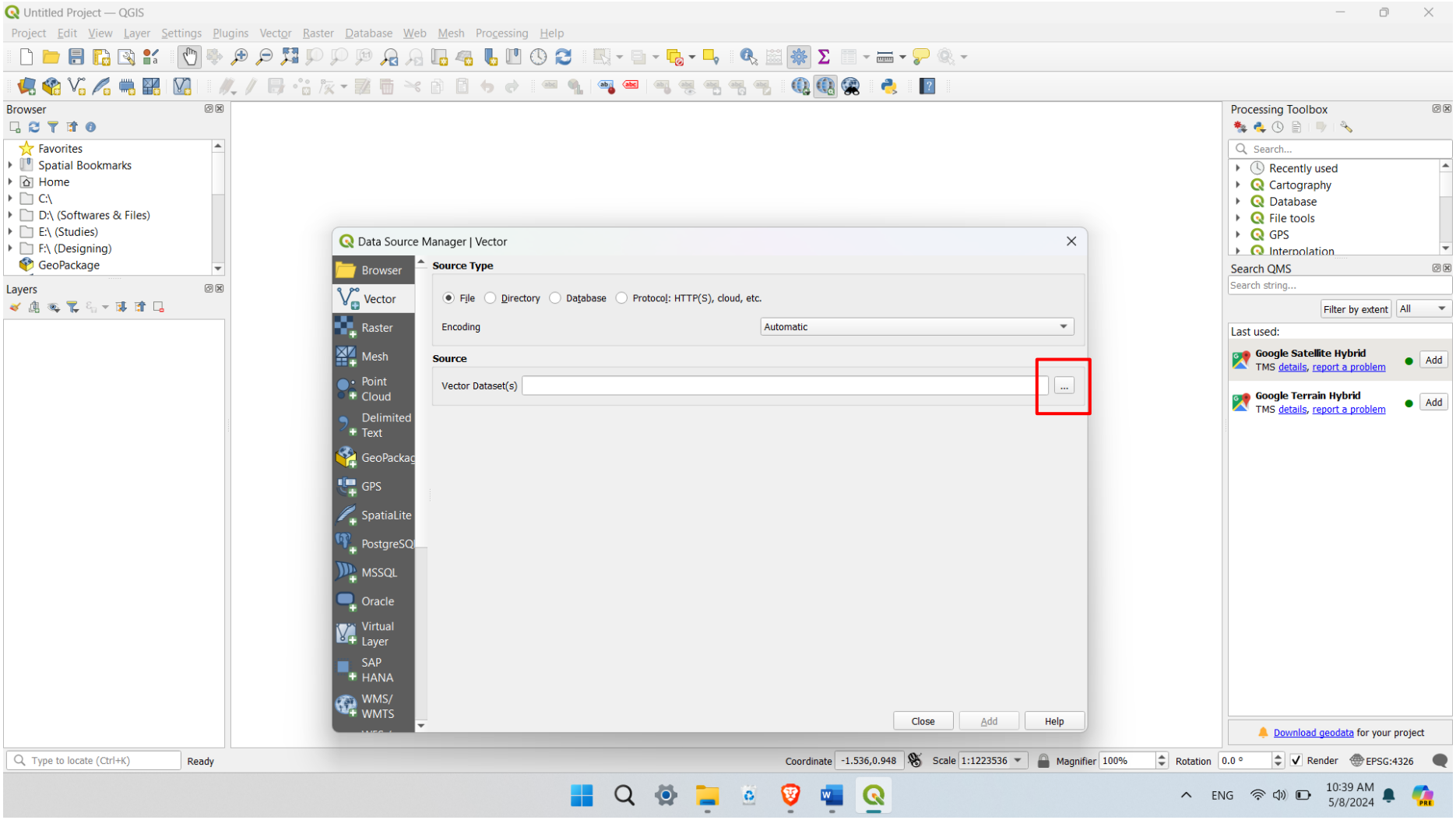
Step 02– Importing vector layers into QGIS

1.1. You can open your vector files with QGIS in the following way using the layer toolbar. (**Layer > Add Layer > Add Vector Layer**)

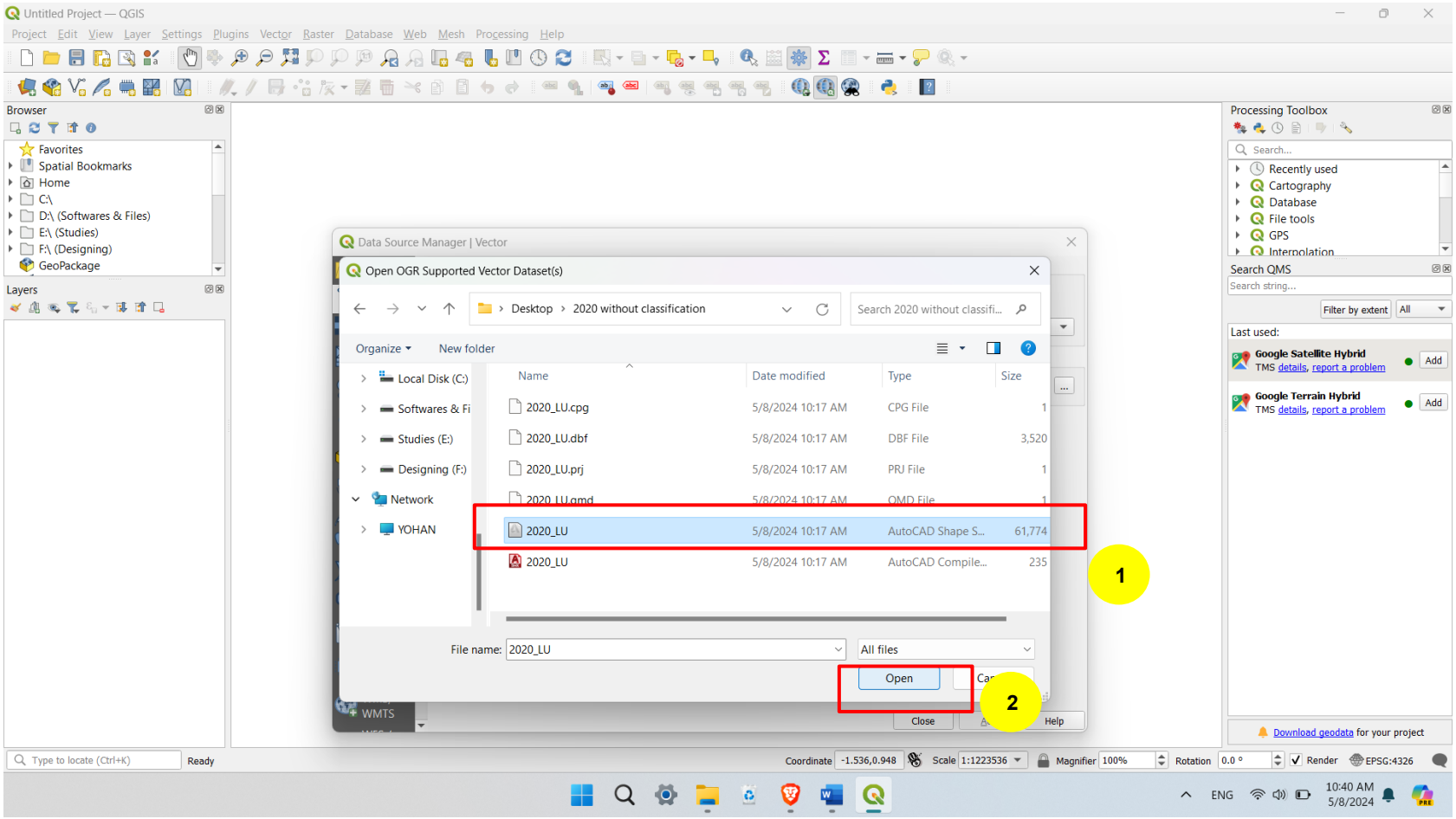
Otherwise, you can use the short key (**Ctrl+Shift+V**) to open the vector files.



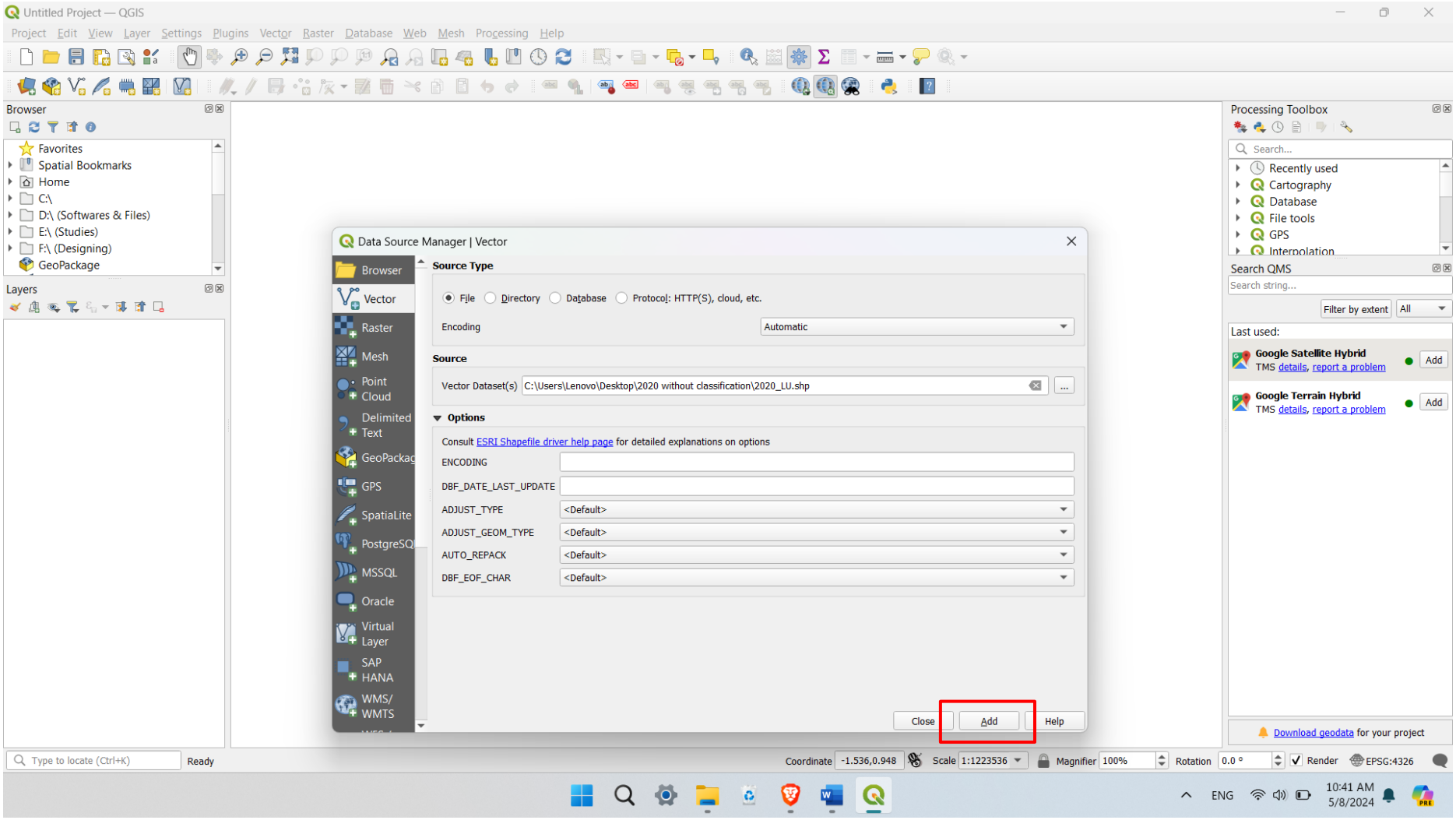
1.2. Then the following window will appear on the screen. You have to browse the location that the data files stored on your computer.



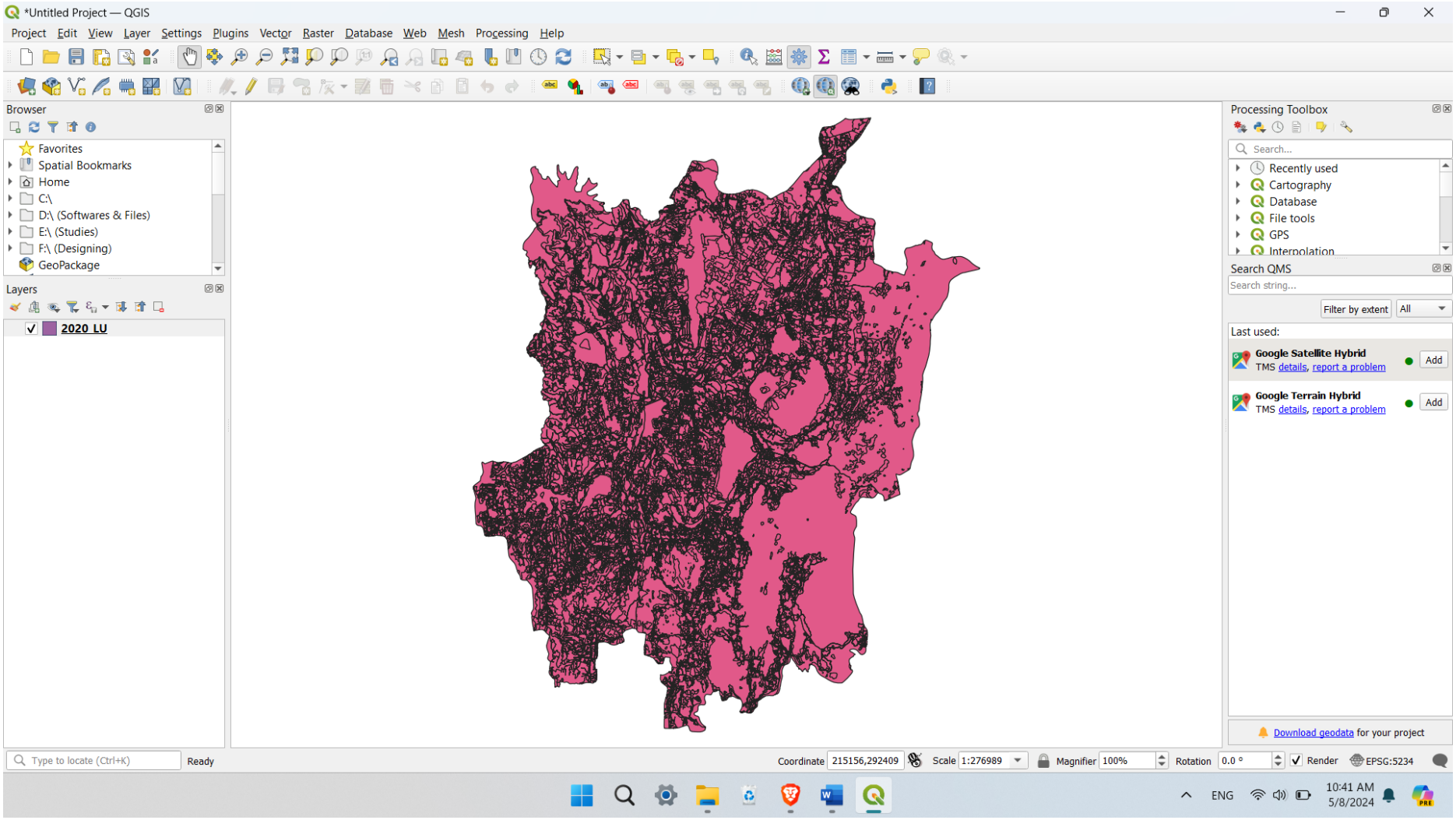
2.3 After clicking on “**Browse**”, the following window will open. Then, go to the relevant folder and select the vector file. Usually, a shape file consists of 6 other files. The file type you should choose to open here is the "**AutoCAD Shape Source**" file. As per the instructions, click on that layer, and after that click on “**Open**”.



2.4 Again, click on “**Add**” to add the layer to the workspace.



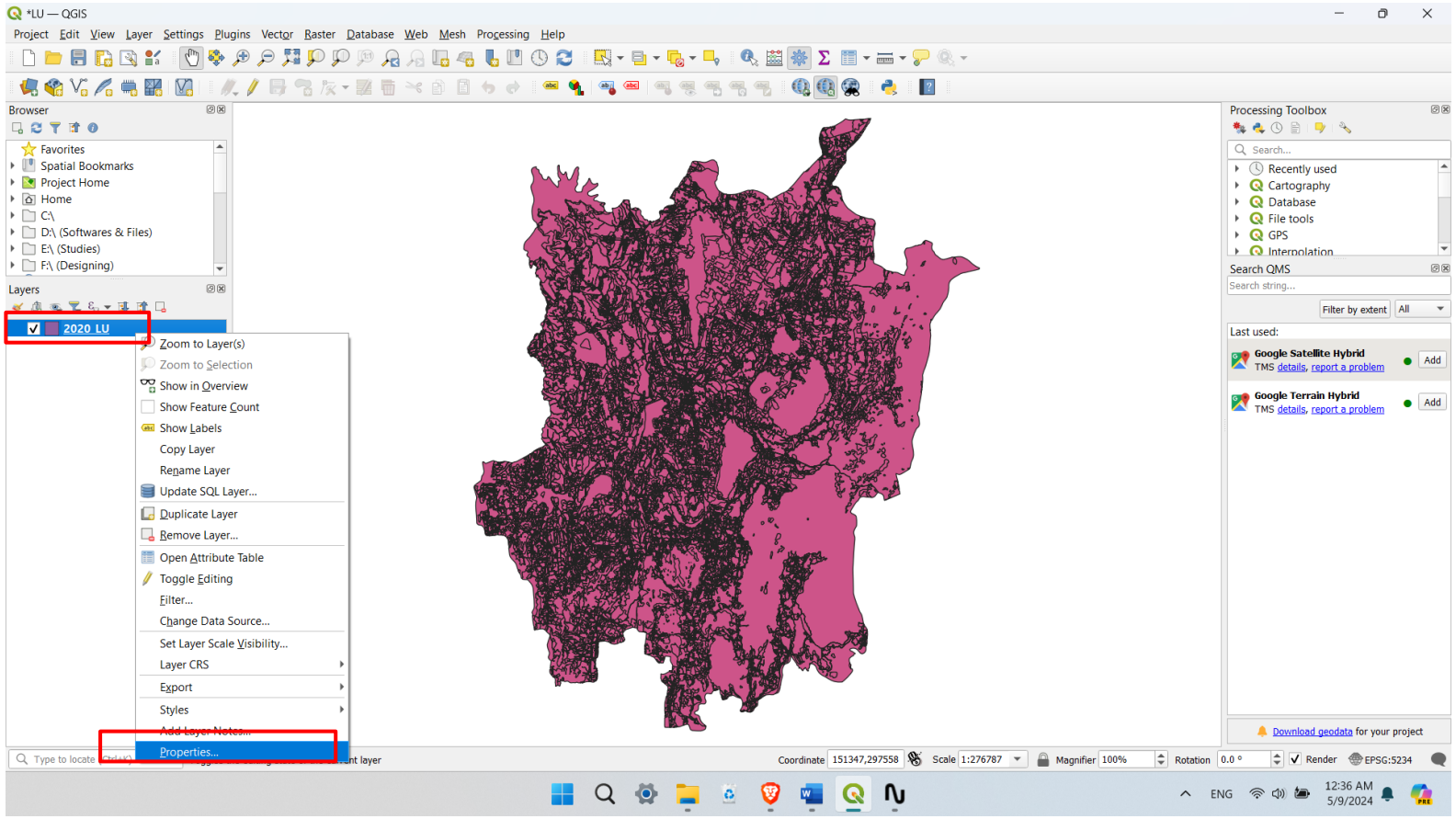
2.5 The land use layer will appear on the screen as follows.



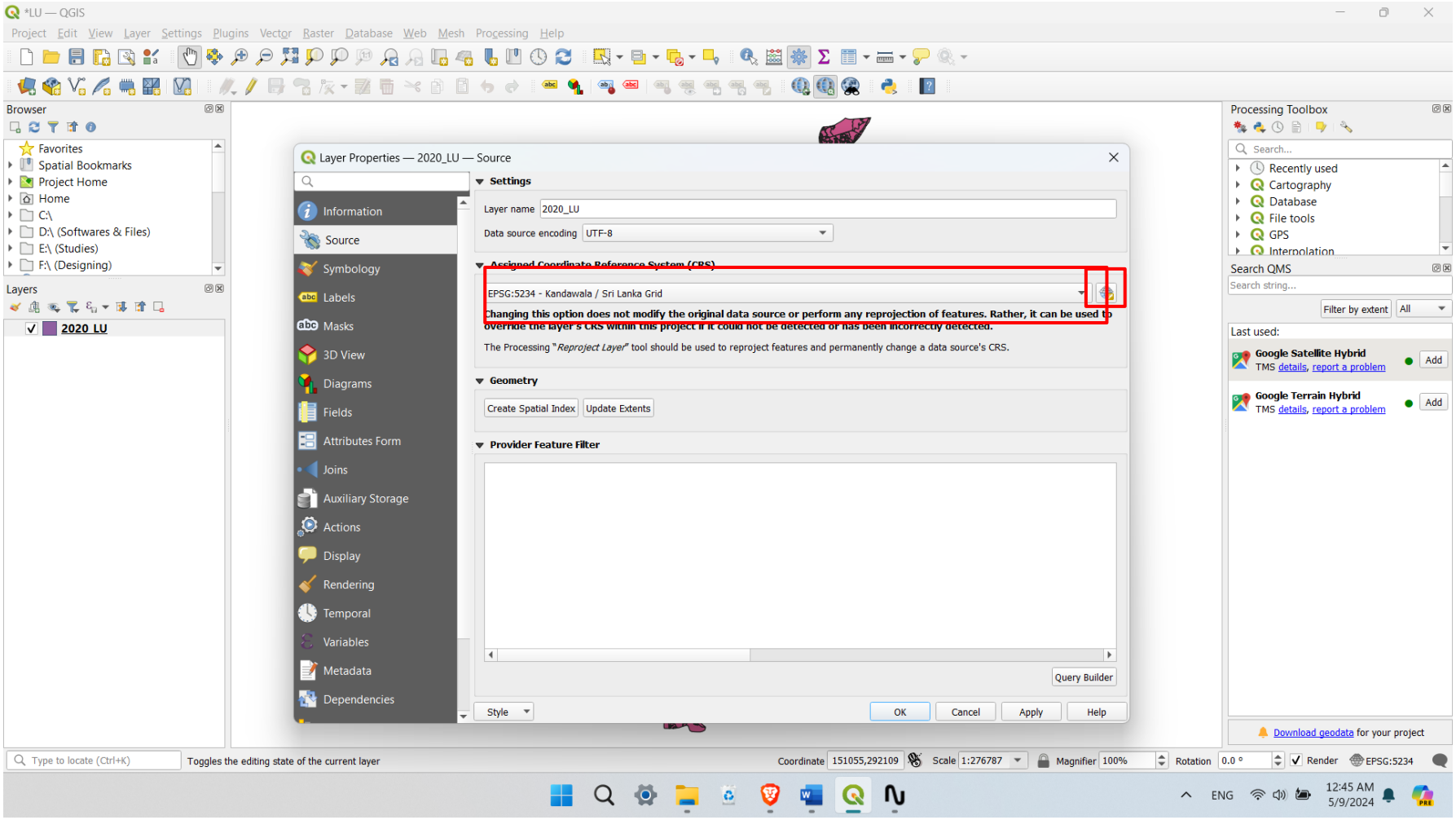
Step 03– Setting up the Coordinate Reference System (CRS)

The Coordinate Reference System of all the layers used for this land use prediction should be the same. The first thing we prepare in this way is the Land Use Layers. Here we choose a Coordinate Reference System for this layer, this Coordinate System must be used for all the layers prepared from now on.

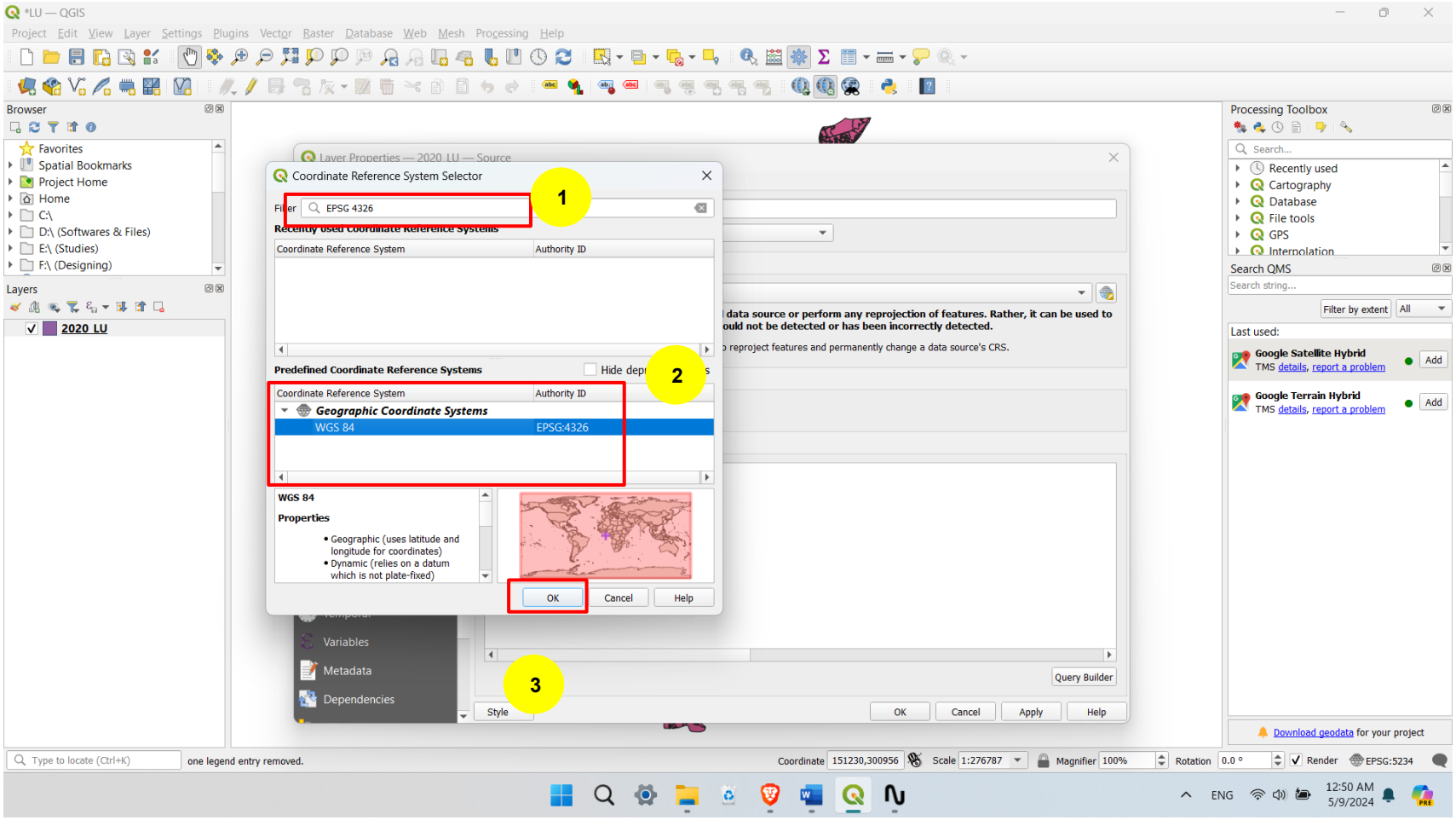
3.1 To set up the Coordinate Reference System, first, right-click on the layer, and click on "**Properties"**. Then, the layer properties will open.



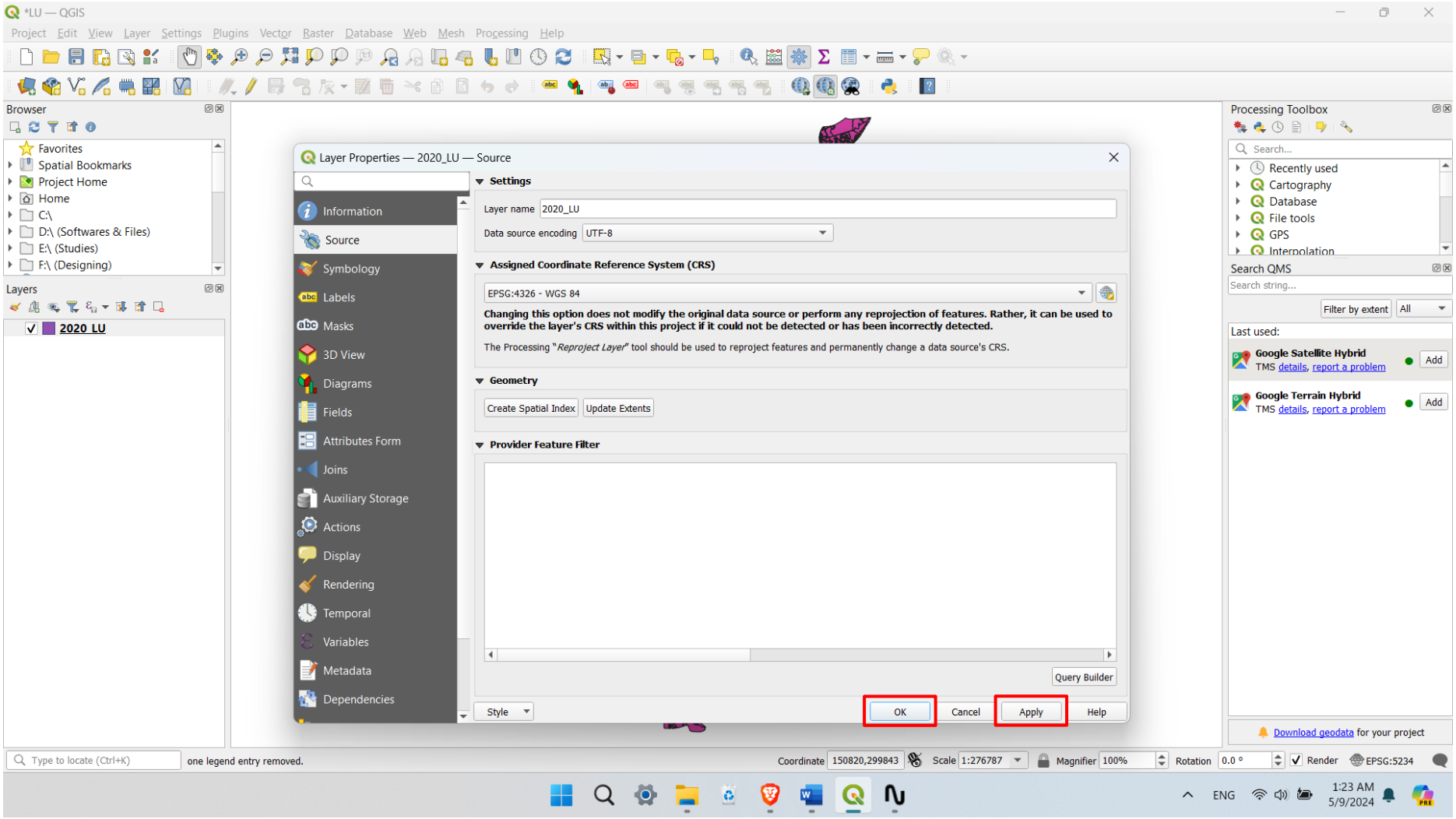
3.2 Under the “**Source**” tab, the assigned coordinate reference system can be seen. If you want to change CRS, click on the icon near the position that the current CSR showing.



3.3 Then, the following “**Coordinate Reference System Selector**” window will open. In this scenario, “**EPSG 4326**” is the CRS that we want to select. For that, type the name in the search bar as follows. Then the CRS will appear under the “Predefined Coordinate Reference Systems”. Simply click on that and click “**OK**” to proceed.

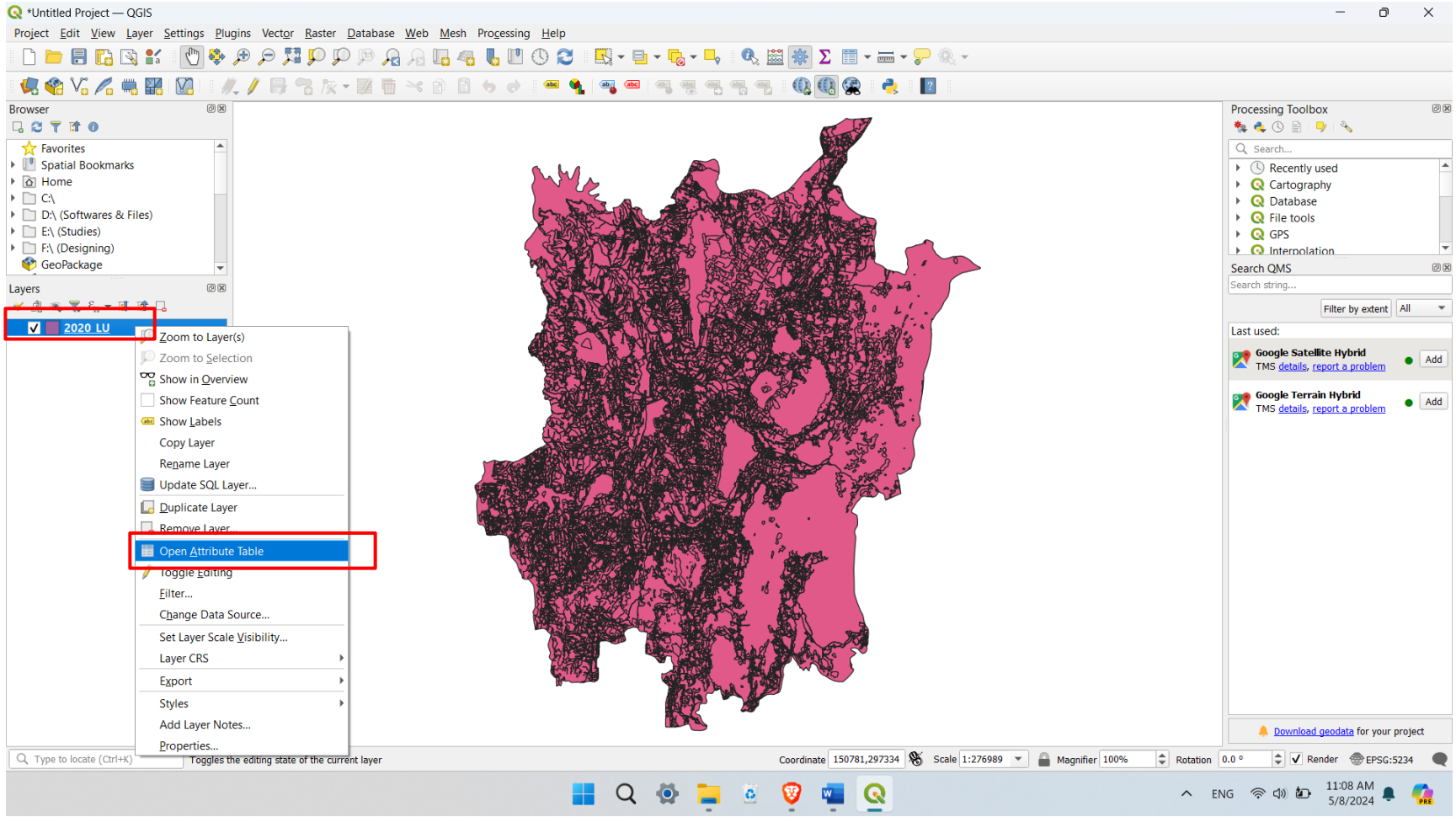


3.4 Now click on “**Apply**” and “**OK**” to change the Coordinate Reference System.

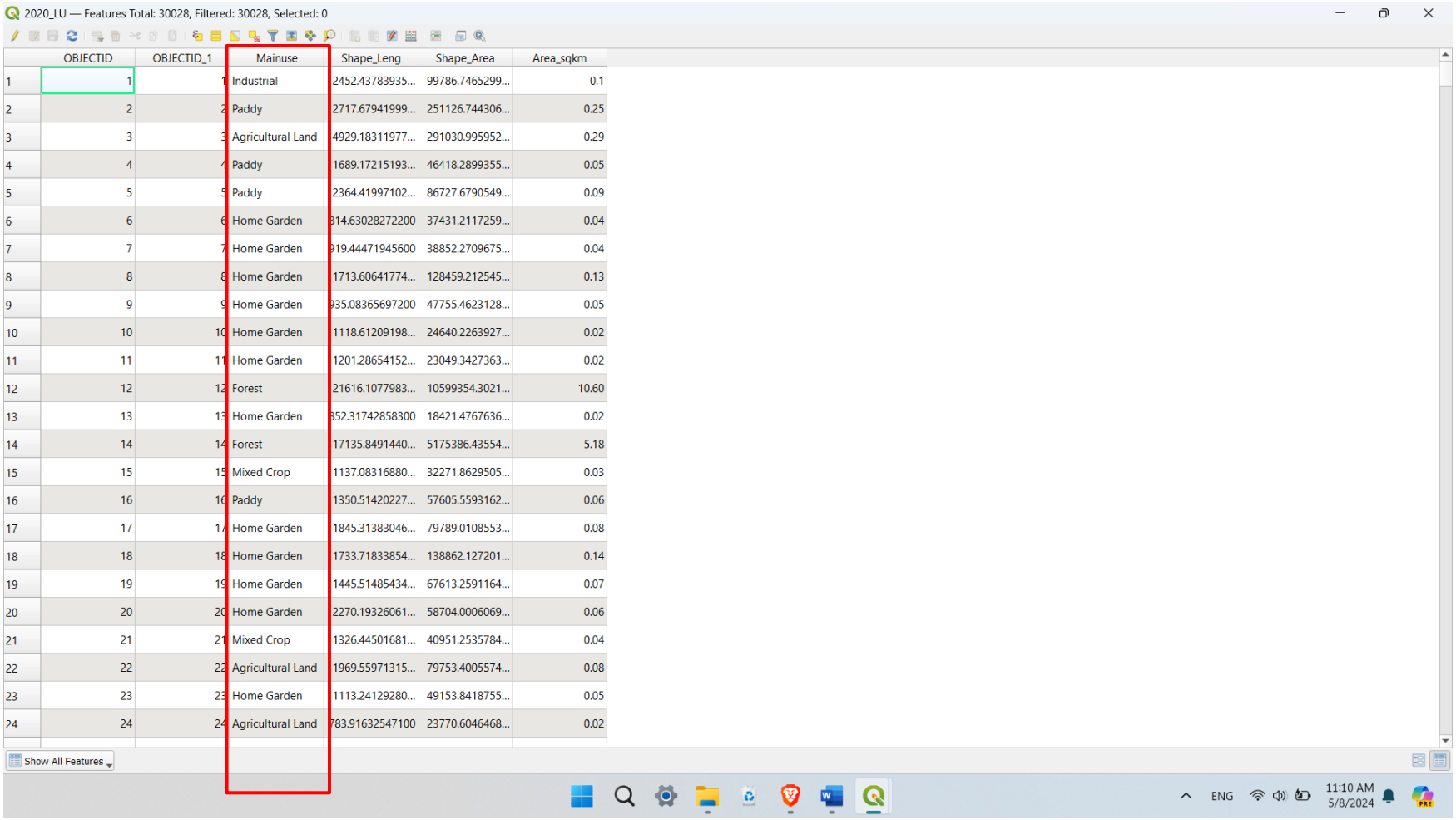


Step 04 – Functions related to updating the Attribute Table

4.1 Now, right-click on the layer and click on "**Open Attribute Table**".



4.2 The Attribute Table of the layer will open as follows. Under the column “**Mainuse**”, we can see the land use of every plot of the Dambulla regional area.



	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm
1	1	1	Industrial	2452.43783935...	99786.7465299...	0.1
2	2	2	Paddy	2717.67941999...	251126.744306...	0.25
3	3	3	Agricultural Land	4929.18311977...	291030.995952...	0.29
4	4	4	Paddy	1689.17215193...	46418.2899355...	0.05
5	5	5	Paddy	2364.41997102...	86727.6790549...	0.09
6	6	6	Home Garden	814.63028272200	37431.2117259...	0.04
7	7	7	Home Garden	919.44471945600	38852.2709675...	0.04
8	8	8	Home Garden	1713.60641774...	128459.212545...	0.13
9	9	9	Home Garden	935.08365697200	47755.4623128...	0.05
10	10	10	Home Garden	1118.61209198...	24640.2263927...	0.02
11	11	11	Home Garden	1201.28654152...	23049.3427363...	0.02
12	12	12	Forest	21616.1077983...	10599354.3021...	10.60
13	13	13	Home Garden	852.31742858300	18421.4767636...	0.02
14	14	14	Forest	17135.8491440...	5175386.43554...	5.18
15	15	15	Mixed Crop	1137.08316880...	32271.8629505...	0.03
16	16	16	Paddy	1350.51420227...	57605.5593162...	0.06
17	17	17	Home Garden	1845.31383046...	79789.0108553...	0.08
18	18	18	Home Garden	1733.71833854...	138862.127201...	0.14
19	19	19	Home Garden	1445.51485434...	67613.2591164...	0.07
20	20	20	Home Garden	2270.19326061...	58704.0006069...	0.06
21	21	21	Mixed Crop	1326.44501681...	40951.2535784...	0.04
22	22	22	Agricultural Land	1969.55971315...	79753.4005574...	0.08
23	23	23	Home Garden	1113.24129280...	49153.8418755...	0.05
24	24	24	Agricultural Land	783.91632547100	23770.6046468...	0.02

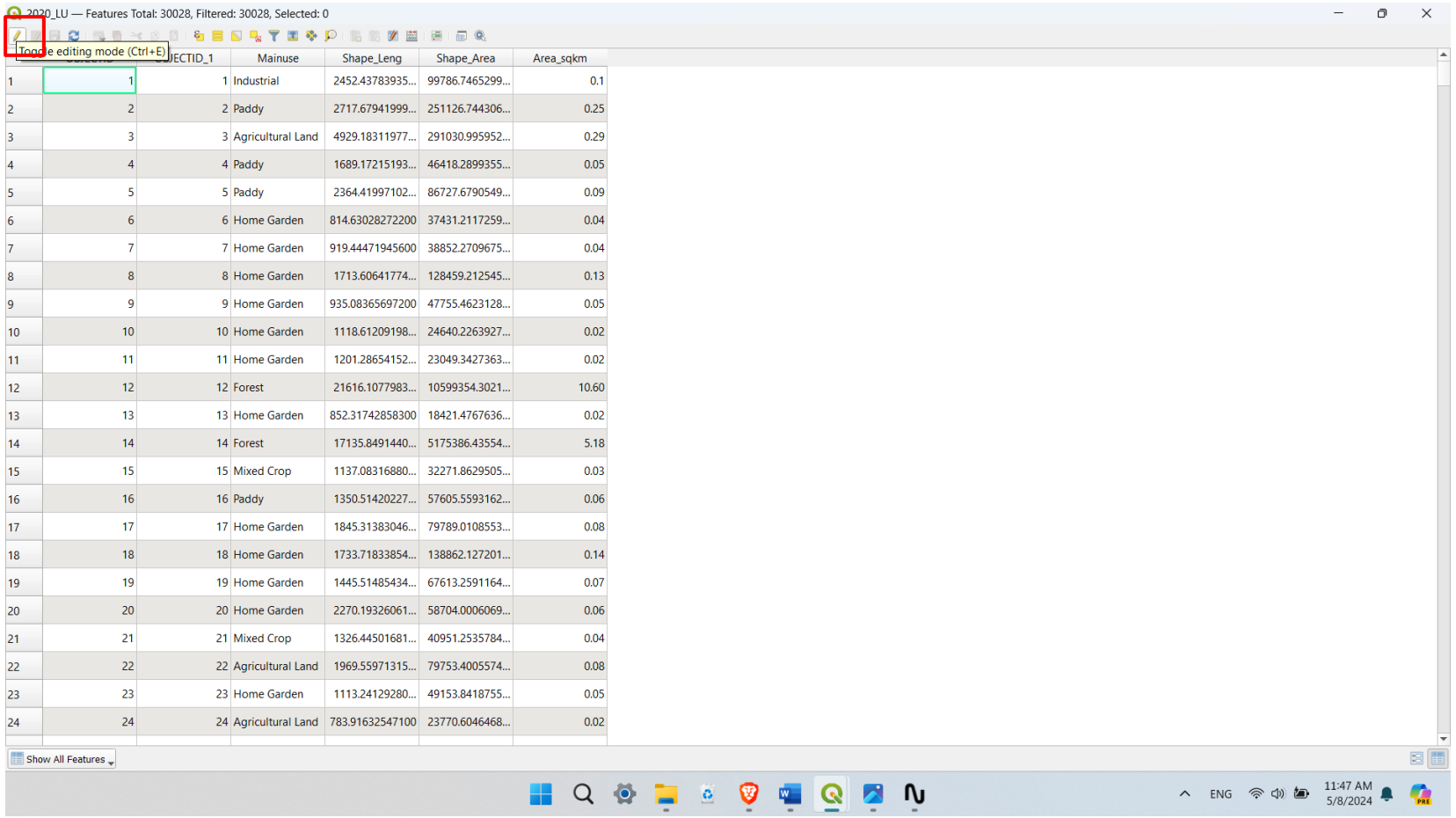
We divide all the above land uses into 4 main categories. They can be shown below.

Agricultural Lands	Built-up Areas	Vegetation	Water Bodies
Agricultural Land Chena Coconut Mixed Crop Paddy	Archeological Sites Aviation Bank & Allied Commercial/ Residential Commercial Educational Health Home Garden Industrial Institutional Open Space RDA Road Other Road Railway Religious Reservation Residential Socio-cultural Sports & Amusement Sores & Warehouse Tourism Transportation Under Construction Utility Vacant Building Vacant Land	Forest Grassland Marshy Plantation Other Plantation Scrub	Water Bodies Catchment Area Dam Abandon Tank River Water Tank

Table 3 -Land use categorization for the selected land use layers

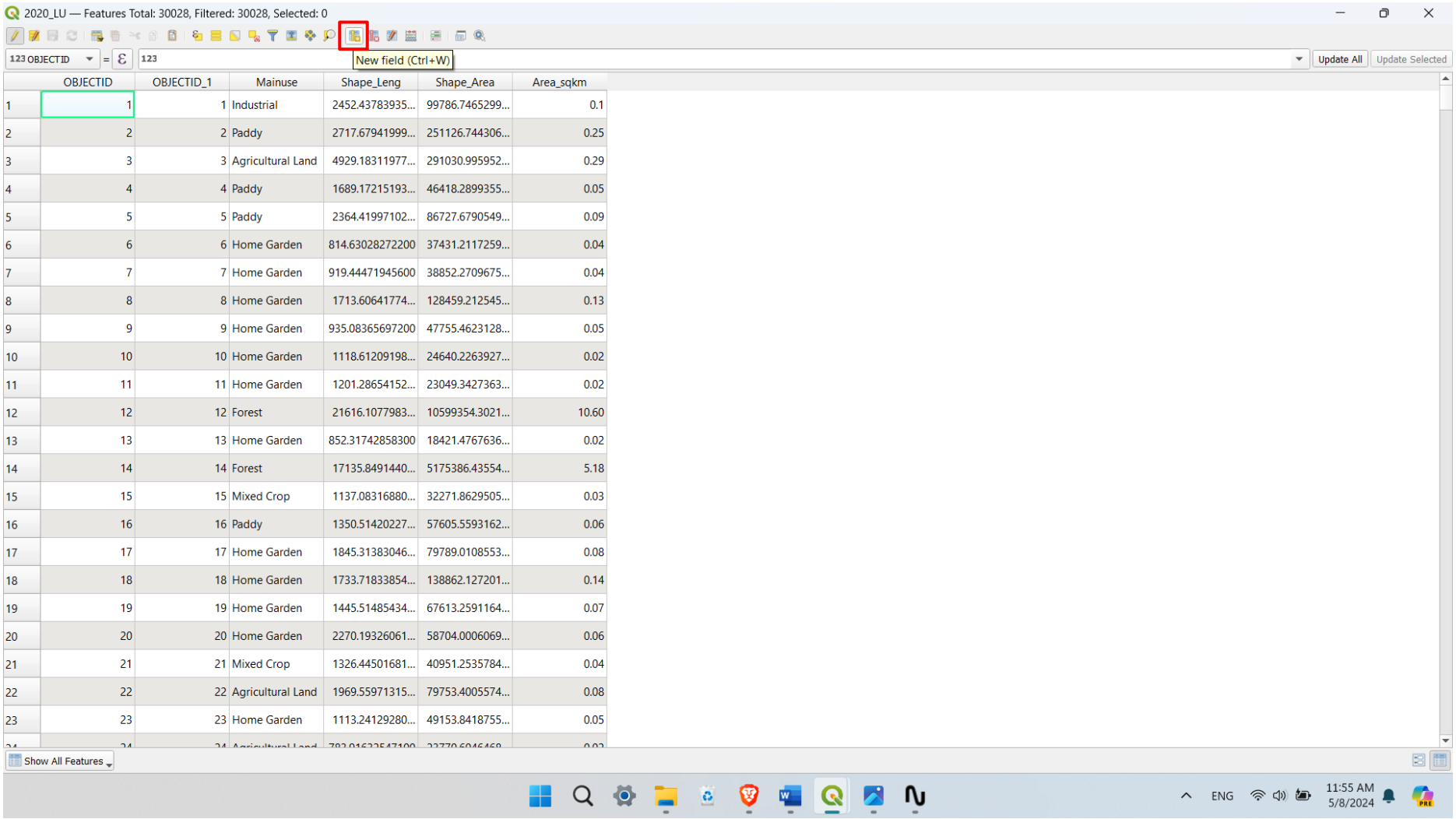
4.3 Next, we update these 4 land use categories in the attribute table above. For that, the following steps should be followed.

- First, we should create a new field in the attribute table named “**2020**”.
- Click on the pencil icon and turn on the “**Toggle editing mode**”.



			Mainuse	Shape_Leng	Shape_Area	Area_sqkm
1	1	1	Industrial	2452.43783935...	99786.7465299...	0.1
2	2	2	Paddy	2717.67941999...	251126.744306...	0.25
3	3	3	Agricultural Land	4929.18311977...	291030.995952...	0.29
4	4	4	Paddy	1689.17215193...	46418.2899355...	0.05
5	5	5	Paddy	2364.41997102...	86727.6790549...	0.09
6	6	6	Home Garden	814.63028272200	37431.2117259...	0.04
7	7	7	Home Garden	919.44471945600	38852.2709675...	0.04
8	8	8	Home Garden	1713.60641774...	128459.212545...	0.13
9	9	9	Home Garden	935.08365697200	47755.4623128...	0.05
10	10	10	Home Garden	1118.61209198...	24640.2263927...	0.02
11	11	11	Home Garden	1201.28654152...	23049.3427363...	0.02
12	12	12	Forest	21616.1077983...	10599354.3021...	10.60
13	13	13	Home Garden	852.31742858300	18421.4767636...	0.02
14	14	14	Forest	17135.8491440...	5175386.43554...	5.18
15	15	15	Mixed Crop	1137.08316880...	32271.8629505...	0.03
16	16	16	Paddy	1350.51420227...	57605.5593162...	0.06
17	17	17	Home Garden	1845.31383046...	79789.0108553...	0.08
18	18	18	Home Garden	1733.71833854...	138862.127201...	0.14
19	19	19	Home Garden	1445.51485434...	67613.2591164...	0.07
20	20	20	Home Garden	2270.19326061...	58704.0006069...	0.06
21	21	21	Mixed Crop	1326.44501681...	40951.2535784...	0.04
22	22	22	Agricultural Land	1969.55971315...	79753.4005574...	0.08
23	23	23	Home Garden	1113.24129280...	49153.8418755...	0.05
24	24	24	Agricultural Land	783.91632547100	23770.6046468...	0.02

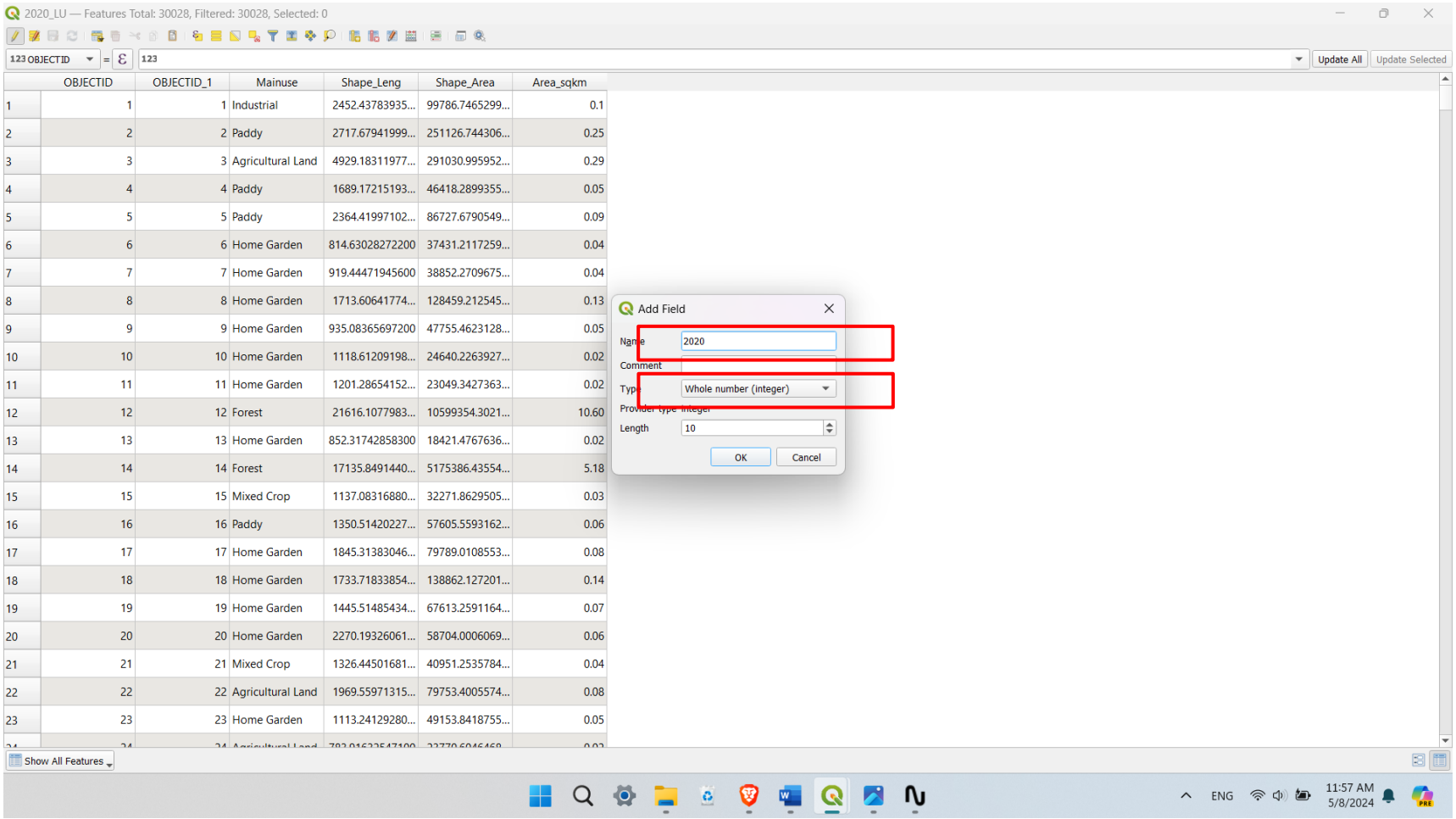
4.4 Now the layer is in editable mode. Then, click on the icon for “**New field**” as follows.



	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm
1	1	1	Industrial	2452.43783935...	99786.7465299...	0.1
2	2	2	Paddy	2717.67941999...	251126.744306...	0.25
3	3	3	Agricultural Land	4929.18311977...	291030.995952...	0.29
4	4	4	Paddy	1689.17215193...	46418.2899355...	0.05
5	5	5	Paddy	2364.41997102...	86727.6790549...	0.09
6	6	6	Home Garden	814.63028272200	37431.2117259...	0.04
7	7	7	Home Garden	919.44471945600	38852.2709675...	0.04
8	8	8	Home Garden	1713.60641774...	128459.212545...	0.13
9	9	9	Home Garden	935.08365697200	47755.4623128...	0.05
10	10	10	Home Garden	1118.61209198...	24640.2263927...	0.02
11	11	11	Home Garden	1201.28654152...	23049.3427363...	0.02
12	12	12	Forest	21616.1077983...	10599354.3021...	10.60
13	13	13	Home Garden	852.31742858300	18421.4767636...	0.02
14	14	14	Forest	17135.8491440...	5175386.43554...	5.18
15	15	15	Mixed Crop	1137.08316880...	32271.8629505...	0.03
16	16	16	Paddy	1350.51420227...	57605.5593162...	0.06
17	17	17	Home Garden	1845.31383046...	79789.0108553...	0.08
18	18	18	Home Garden	1733.71833854...	138862.127201...	0.14
19	19	19	Home Garden	1445.51485434...	67613.2591164...	0.07
20	20	20	Home Garden	2270.19326061...	58704.0006069...	0.06
21	21	21	Mixed Crop	1326.44501681...	40951.2535784...	0.04
22	22	22	Agricultural Land	1969.55971315...	79753.4005574...	0.08
23	23	23	Home Garden	1113.24129280...	49153.8418755...	0.05

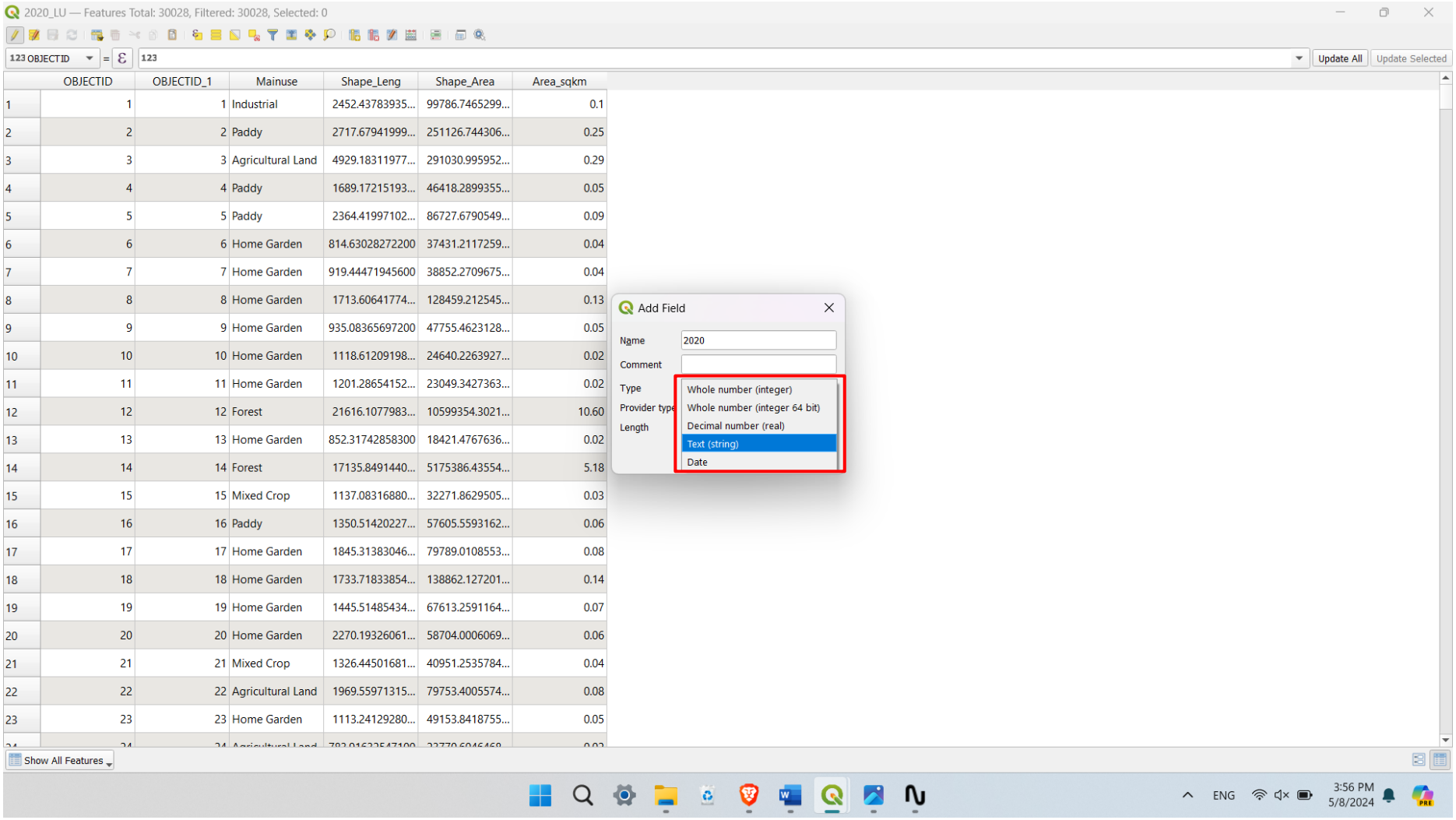
4.5 After clicking on the “**New field**” icon, the following window will open. Then, enter the **Name** as “**2020**”.

4.6 Then, you have to select the type of the field. For that, expand the “**Type**” option here.



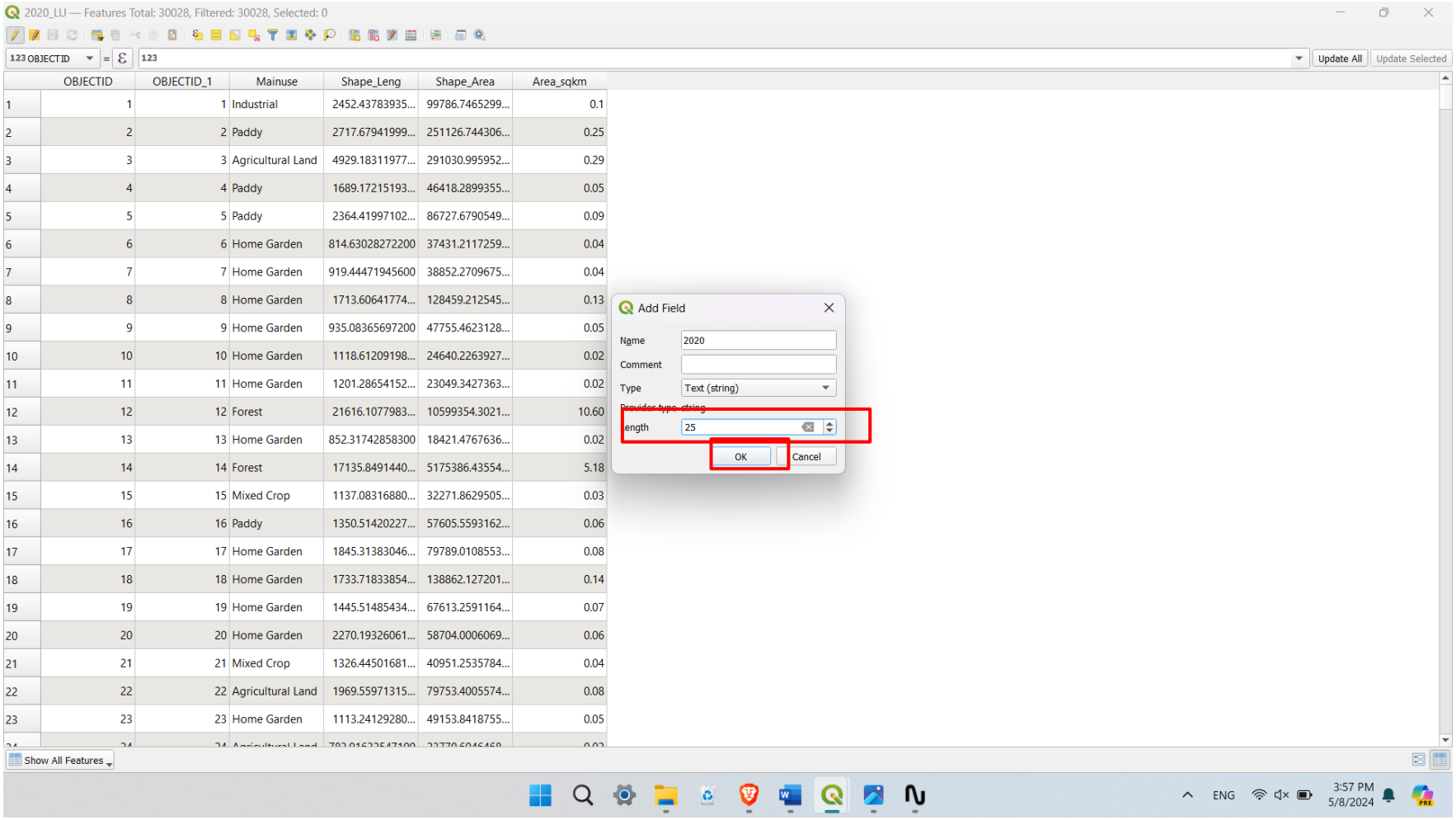
	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm
1	1	1	Industrial	2452.43783935...	99786.7465299...	0.1
2	2	2	Paddy	2717.67941999...	251126.744306...	0.25
3	3	3	Agricultural Land	4929.18311977...	291030.995952...	0.29
4	4	4	Paddy	1689.17215193...	46418.2899355...	0.05
5	5	5	Paddy	2364.41997102...	86727.6790549...	0.09
6	6	6	Home Garden	814.63028272200	37431.2117259...	0.04
7	7	7	Home Garden	919.44471945600	38852.2709675...	0.04
8	8	8	Home Garden	1713.60641774...	128459.212545...	0.13
9	9	9	Home Garden	935.08365697200	47755.4623128...	0.05
10	10	10	Home Garden	1118.61209198...	24640.2263927...	0.02
11	11	11	Home Garden	1201.28654152...	23049.3427363...	0.02
12	12	12	Forest	21616.1077983...	10599354.3021...	10.60
13	13	13	Home Garden	852.31742858300	18421.4767636...	0.02
14	14	14	Forest	17135.8491440...	5175386.43554...	5.18
15	15	15	Mixed Crop	1137.08316880...	32271.8629505...	0.03
16	16	16	Paddy	1350.51420227...	57605.5593162...	0.06
17	17	17	Home Garden	1845.31383046...	79789.0108553...	0.08
18	18	18	Home Garden	1733.71833854...	138862.127201...	0.14
19	19	19	Home Garden	1445.51485434...	67613.2591164...	0.07
20	20	20	Home Garden	2270.19326061...	58704.0006069...	0.06
21	21	21	Mixed Crop	1326.44501681...	40951.2535784...	0.04
22	22	22	Agricultural Land	1969.55971315...	79753.4005574...	0.08
23	23	23	Home Garden	1113.24129280...	49153.8418755...	0.05

4.7 We are going to enter a text in this field. Therefore, the type named "**Text (string)**" should be selected.



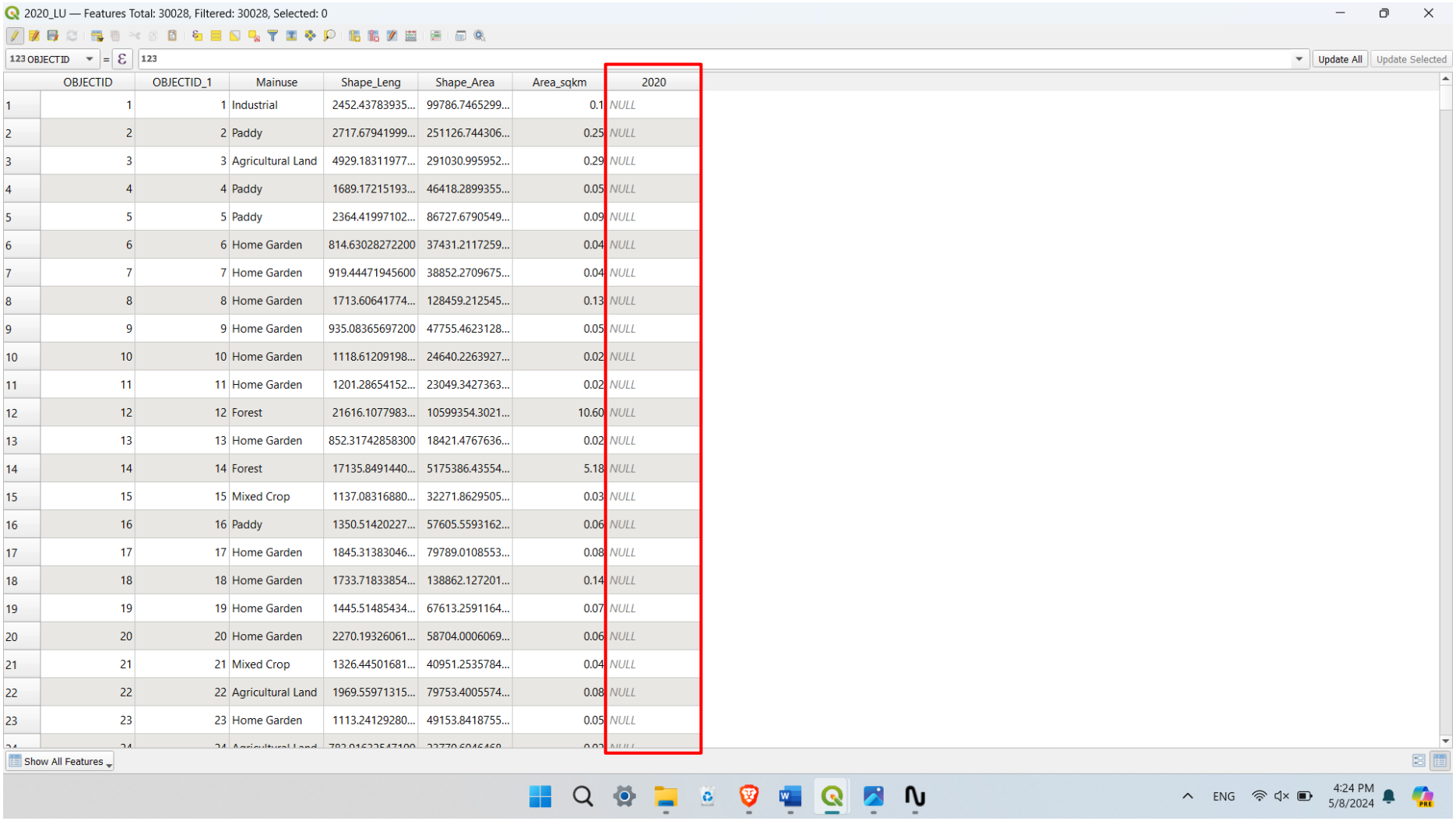
	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm
1	1	1	Industrial	2452.43783935...	99786.7465299...	0.1
2	2	2	Paddy	2717.67941999...	251126.744306...	0.25
3	3	3	Agricultural Land	4929.18311977...	291030.995952...	0.29
4	4	4	Paddy	1689.17215193...	46418.2899355...	0.05
5	5	5	Paddy	2364.41997102...	86727.6790549...	0.09
6	6	6	Home Garden	814.63028272200	37431.2117259...	0.04
7	7	7	Home Garden	919.44471945600	38852.2709675...	0.04
8	8	8	Home Garden	1713.60641774...	128459.212545...	0.13
9	9	9	Home Garden	935.08365697200	47755.4623128...	0.05
10	10	10	Home Garden	1118.61209198...	24640.2263927...	0.02
11	11	11	Home Garden	1201.28654152...	23049.3427363...	0.02
12	12	12	Forest	21616.1077983...	10599354.3021...	10.60
13	13	13	Home Garden	852.31742858300	18421.4767636...	0.02
14	14	14	Forest	17135.8491440...	5175386.43554...	5.18
15	15	15	Mixed Crop	1137.08316880...	32271.8629505...	0.03
16	16	16	Paddy	1350.51420227...	57605.5593162...	0.06
17	17	17	Home Garden	1845.31383046...	79789.0108553...	0.08
18	18	18	Home Garden	1733.71833854...	138862.127201...	0.14
19	19	19	Home Garden	1445.51485434...	67613.2591164...	0.07
20	20	20	Home Garden	2270.19326061...	58704.0006069...	0.06
21	21	21	Mixed Crop	1326.44501681...	40951.2535784...	0.04
22	22	22	Agricultural Land	1969.55971315...	79753.4005574...	0.08
23	23	23	Home Garden	1113.24129280...	49153.8418755...	0.05

4.8 Since I am going to type a word here, I will set the text length as "**25**". But we can specify the amount we need according to the length of the word or several words we use. After setting all these, click on "**OK**" to proceed.



	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm
1	1	1	Industrial	2452.43783935...	99786.7465299...	0.1
2	2	2	Paddy	2717.67941999...	251126.744306...	0.25
3	3	3	Agricultural Land	4929.18311977...	291030.995952...	0.29
4	4	4	Paddy	1689.17215193...	46418.2899355...	0.05
5	5	5	Paddy	2364.41997102...	86727.6790549...	0.09
6	6	6	Home Garden	814.63028272200	37431.2117259...	0.04
7	7	7	Home Garden	919.44471945600	38852.2709675...	0.04
8	8	8	Home Garden	1713.60641774...	128459.212545...	0.13
9	9	9	Home Garden	935.08365697200	47755.4623128...	0.05
10	10	10	Home Garden	1118.61209198...	24640.2263927...	0.02
11	11	11	Home Garden	1201.28654152...	23049.3427363...	0.02
12	12	12	Forest	21616.1077983...	10599354.3021...	10.60
13	13	13	Home Garden	852.31742858300	18421.4767636...	0.02
14	14	14	Forest	17135.8491440...	5175386.43554...	5.18
15	15	15	Mixed Crop	1137.08316880...	32271.8629505...	0.03
16	16	16	Paddy	1350.51420227...	57605.5593162...	0.06
17	17	17	Home Garden	1845.31383046...	79789.0108553...	0.08
18	18	18	Home Garden	1733.71833854...	138862.127201...	0.14
19	19	19	Home Garden	1445.51485434...	67613.2591164...	0.07
20	20	20	Home Garden	2270.19326061...	58704.0006069...	0.06
21	21	21	Mixed Crop	1326.44501681...	40951.2535784...	0.04
22	22	22	Agricultural Land	1969.55971315...	79753.4005574...	0.08
23	23	23	Home Garden	1113.24129280...	49153.8418755...	0.05

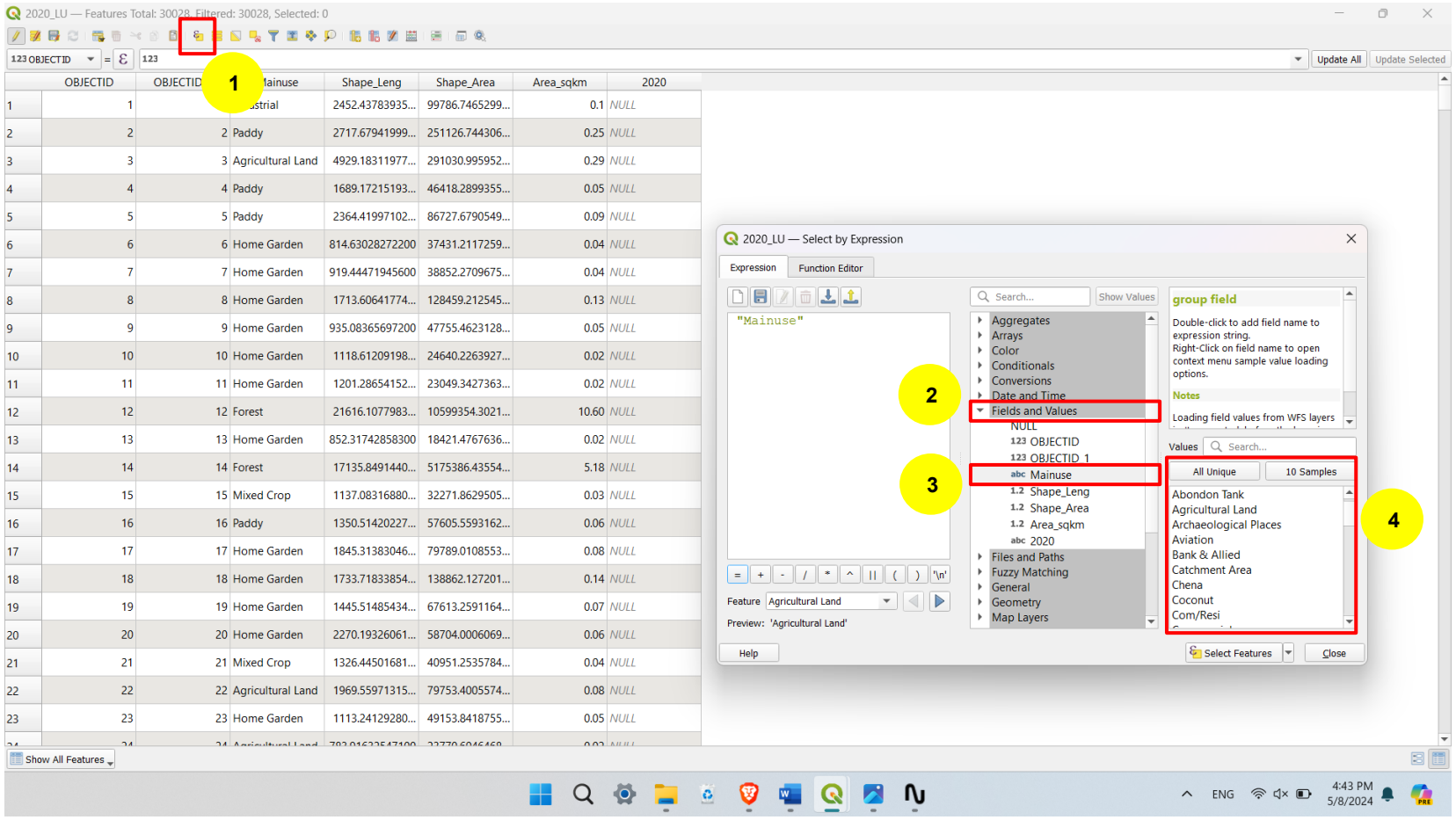
4.9 Now, the newly added field will be shown as follows.



	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm	2020
1	1	1	Industrial	2452.43783935...	99786.7465299...	0.1	NULL
2	2	2	Paddy	2717.67941999...	251126.744306...	0.25	NULL
3	3	3	Agricultural Land	4929.18311977...	291030.995952...	0.29	NULL
4	4	4	Paddy	1689.17215193...	46418.2899355...	0.05	NULL
5	5	5	Paddy	2364.41997102...	86727.6790549...	0.09	NULL
6	6	6	Home Garden	814.63028272200	37431.2117259...	0.04	NULL
7	7	7	Home Garden	919.44471945600	38852.2709675...	0.04	NULL
8	8	8	Home Garden	1713.60641774...	128459.212545...	0.13	NULL
9	9	9	Home Garden	935.08365697200	47755.4623128...	0.05	NULL
10	10	10	Home Garden	1118.61209198...	24640.2263927...	0.02	NULL
11	11	11	Home Garden	1201.28654152...	23049.3427363...	0.02	NULL
12	12	12	Forest	21616.1077983...	10599354.3021...	10.60	NULL
13	13	13	Home Garden	852.31742858300	18421.4767636...	0.02	NULL
14	14	14	Forest	17135.8491440...	5175386.43554...	5.18	NULL
15	15	15	Mixed Crop	1137.08316880...	32271.8629505...	0.03	NULL
16	16	16	Paddy	1350.51420227...	57605.5593162...	0.06	NULL
17	17	17	Home Garden	1845.31383046...	79789.0108553...	0.08	NULL
18	18	18	Home Garden	1733.71833854...	138862.127201...	0.14	NULL
19	19	19	Home Garden	1445.51485434...	67613.2591164...	0.07	NULL
20	20	20	Home Garden	2270.19326061...	58704.0006069...	0.06	NULL
21	21	21	Mixed Crop	1326.44501681...	40951.2535784...	0.04	NULL
22	22	22	Agricultural Land	1969.55971315...	79753.4005574...	0.08	NULL
23	23	23	Home Garden	1113.24129280...	49153.8418755...	0.05	NULL

4.10 Now, we have to add the values into this new field. For that, we should filter each land use from the attribute table, according to our classification.

1. Open the "**Select by the expression**". Then, the following window will open.
2. Click on the "**>**" mark and expand the "**Fields and Values**". Or you can double-click on the "Fields and Values" to expand it.
3. Double-click on "**Mainuse**".
4. Click on "**all unique**". All the characters under the "**Mainuse**" will be shown as follows.

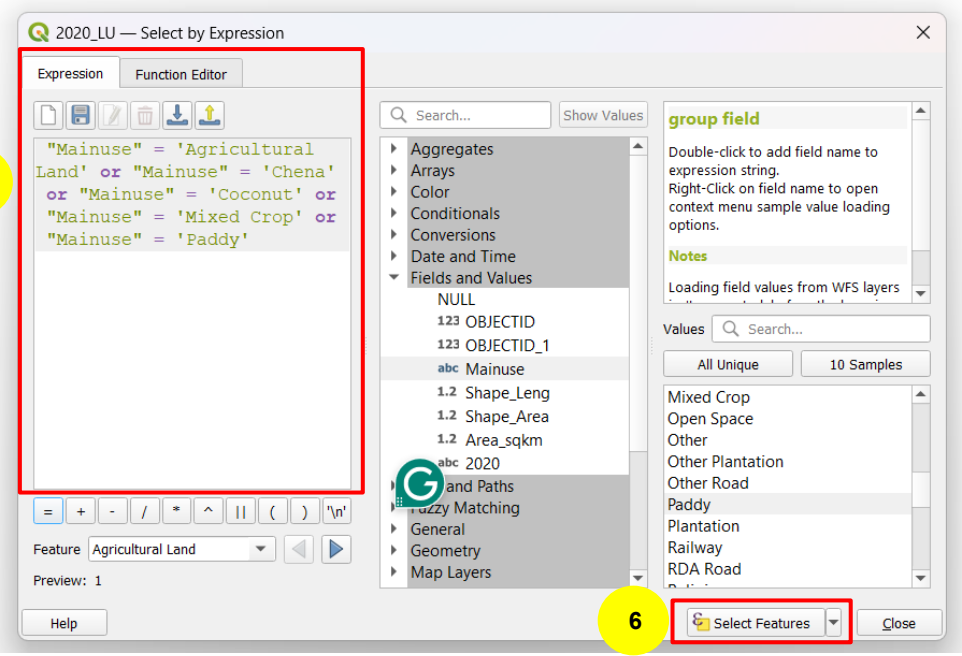


5. Then, you have to enter the following expression on the expression tab. For that, double-click on “**Mainuse**”, type “**=**”, and double-click on the relevant land use category according to our classification.

According to the above steps, first, select the land uses under the category "**Agricultural Lands**". Once done entering a land use using this [**“Mainuse” = ‘Agricultural Land’**], type “**or**” and follow the same steps to add other land use categories into the expression. The “or” operator is used here to create a logical condition that selects features based on multiple criteria.

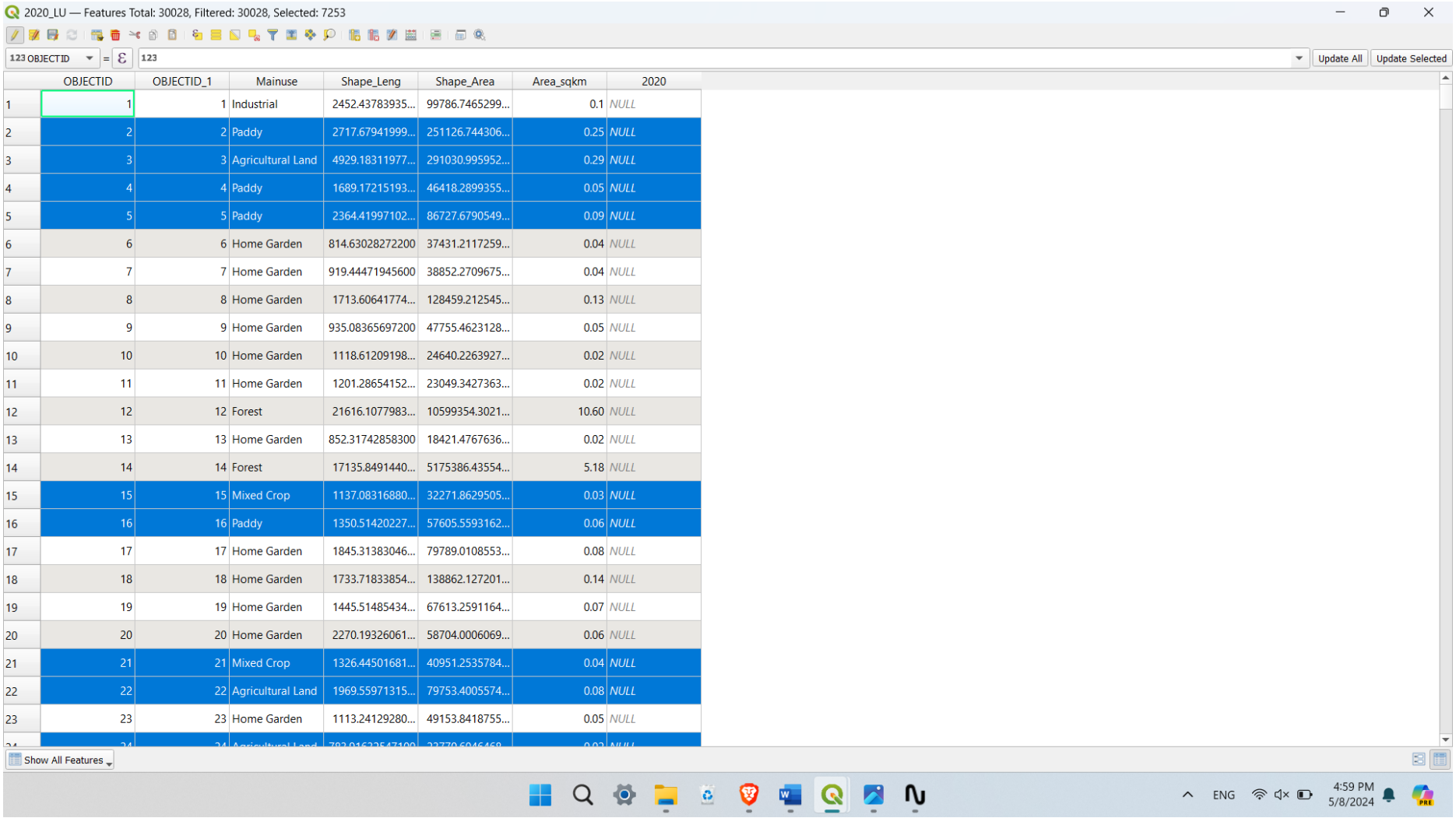
- So, add each land use continuously in this way,

  “Mainuse” = ‘Agricultural Land’ or “Mainuse” = ‘Chena’ or “Mainuse” = ‘Coconut’ or “Mainuse” = ‘Mixed Crop’ or “Mainuse” = ‘Paddy’



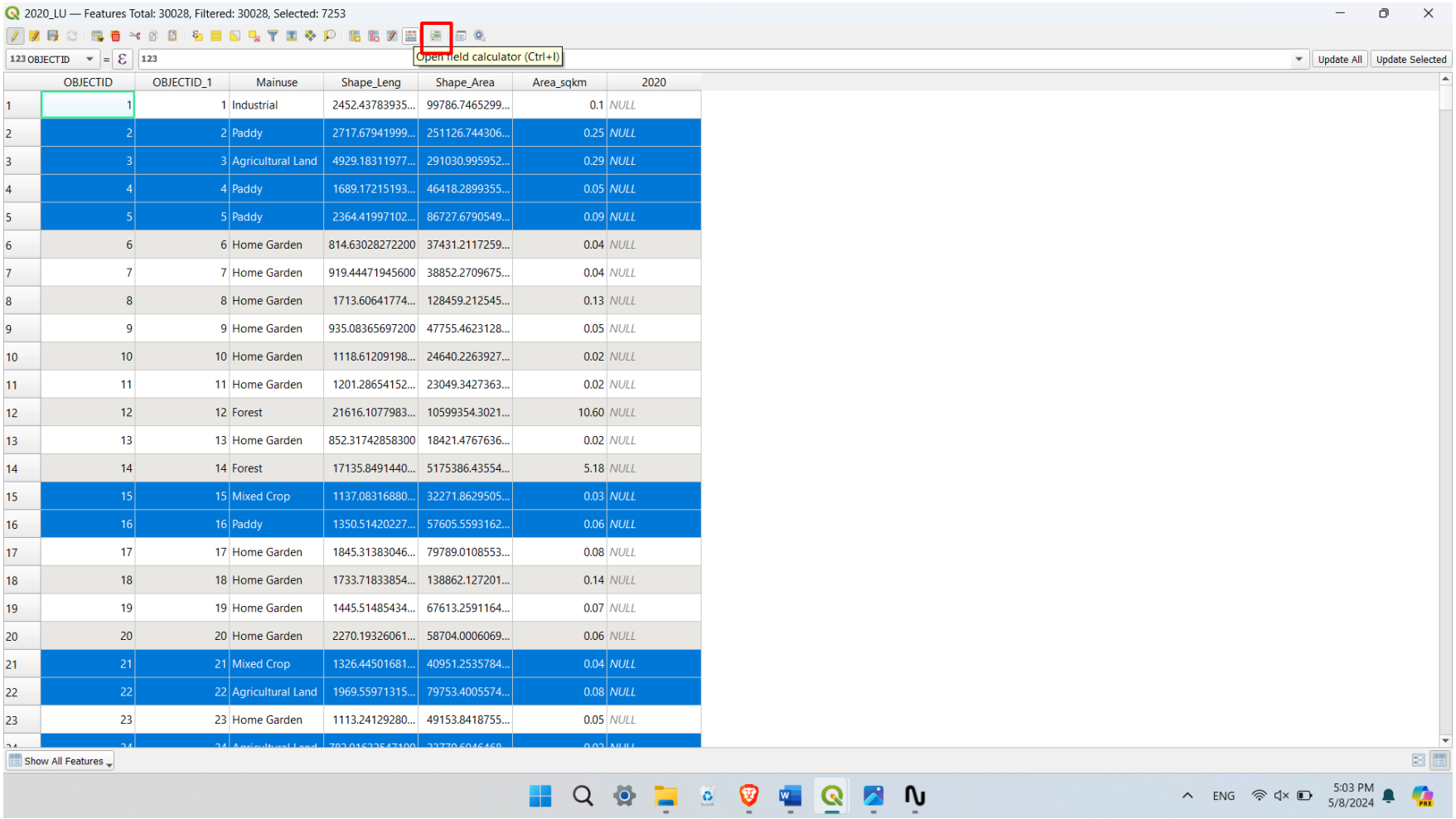
After entering all land use categories into the expression using the above way, click on “**Select Features**”.

The selected data will be shown as follows in the blue color.



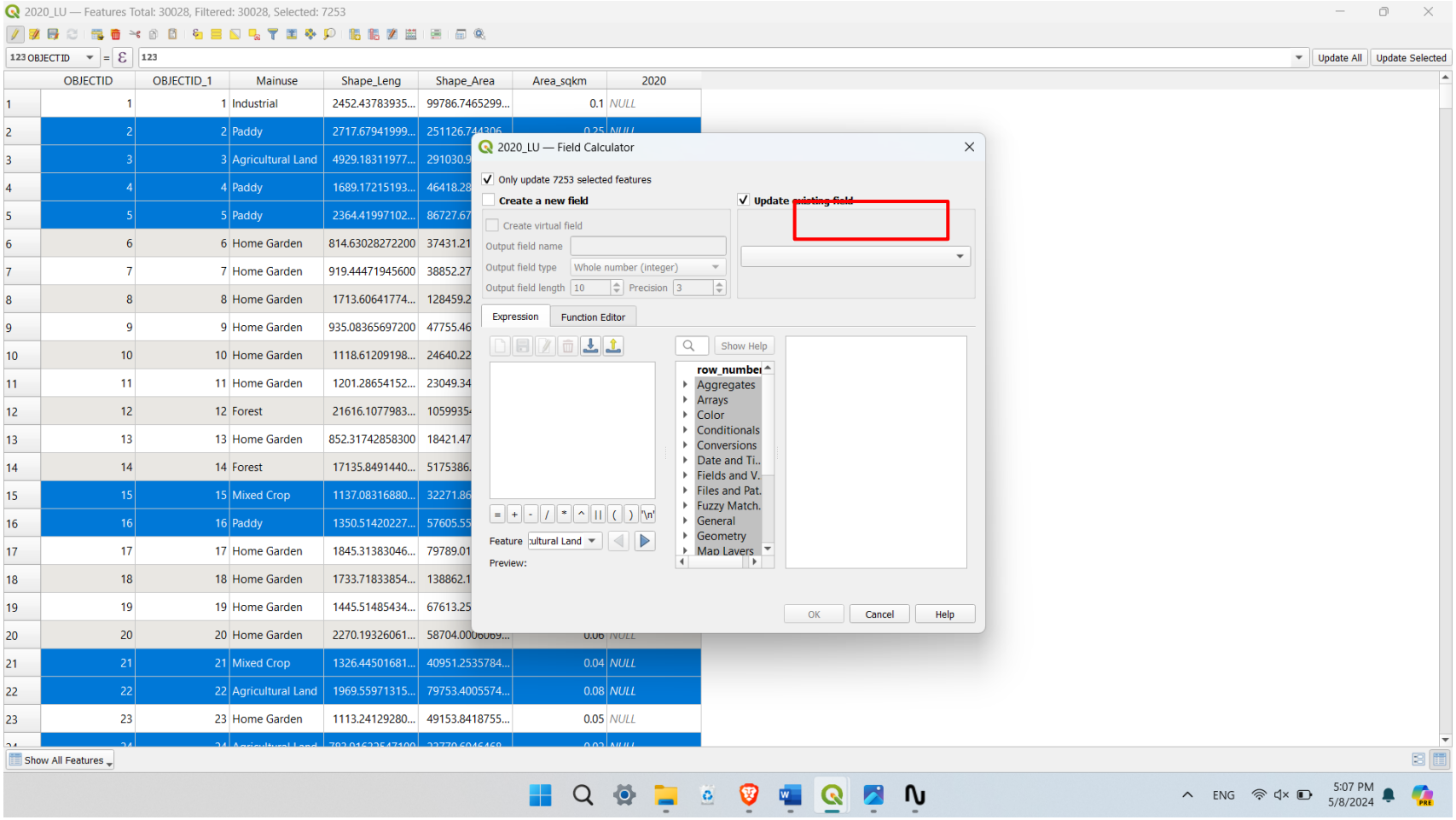
	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm	2020
1	1	1	Industrial	2452.43783935...	99786.7465299...	0.1	NULL
2	2	2	Paddy	2717.67941999...	251126.744306...	0.25	NULL
3	3	3	Agricultural Land	4929.18311977...	291030.995952...	0.29	NULL
4	4	4	Paddy	1689.17215193...	46418.2899355...	0.05	NULL
5	5	5	Paddy	2364.41997102...	86727.6790549...	0.09	NULL
6	6	6	Home Garden	814.63028272200	37431.2117259...	0.04	NULL
7	7	7	Home Garden	919.44471945600	38852.2709675...	0.04	NULL
8	8	8	Home Garden	1713.60641774...	128459.212545...	0.13	NULL
9	9	9	Home Garden	935.08365697200	47755.4623128...	0.05	NULL
10	10	10	Home Garden	1118.61209198...	24640.2263927...	0.02	NULL
11	11	11	Home Garden	1201.28654152...	23049.3427363...	0.02	NULL
12	12	12	Forest	21616.1077983...	10599354.3021...	10.60	NULL
13	13	13	Home Garden	852.31742858300	18421.4767636...	0.02	NULL
14	14	14	Forest	17135.8491440...	5175386.43554...	5.18	NULL
15	15	15	Mixed Crop	1137.08316880...	32271.8629505...	0.03	NULL
16	16	16	Paddy	1350.51420227...	57605.5593162...	0.06	NULL
17	17	17	Home Garden	1845.31383046...	79789.0108553...	0.08	NULL
18	18	18	Home Garden	1733.71833854...	138862.127201...	0.14	NULL
19	19	19	Home Garden	1445.51485434...	67613.2591164...	0.07	NULL
20	20	20	Home Garden	2270.19326061...	58704.0006069...	0.06	NULL
21	21	21	Mixed Crop	1326.44501681...	40951.2535784...	0.04	NULL
22	22	22	Agricultural Land	1969.55971315...	79753.4005574...	0.08	NULL
23	23	23	Home Garden	1113.24129280...	49153.8418755...	0.05	NULL

4.11 In the next step, we have to add the text for the “**2020**” column. According to the above steps, we selected here the land use categories for the category "**Agricultural Lands**". For that, click on the icon for “**Open field calculator**”.



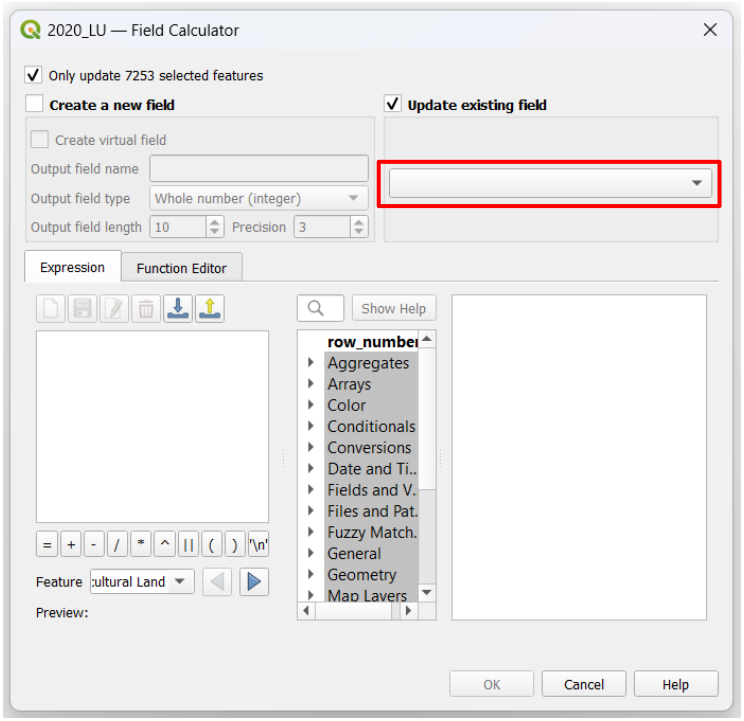
	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm	2020
1	1	1	Industrial	2452.43783935...	99786.7465299...	0.1	NULL
2	2	2	Paddy	2717.67941999...	251126.744306...	0.25	NULL
3	3	3	Agricultural Land	4929.18311977...	291030.995952...	0.29	NULL
4	4	4	Paddy	1689.17215193...	46418.2899355...	0.05	NULL
5	5	5	Paddy	2364.41997102...	86727.6790549...	0.09	NULL
6	6	6	Home Garden	814.63028272200	37431.2117259...	0.04	NULL
7	7	7	Home Garden	919.44471945600	38852.2709675...	0.04	NULL
8	8	8	Home Garden	1713.60641774...	128459.212545...	0.13	NULL
9	9	9	Home Garden	935.08365697200	47755.4623128...	0.05	NULL
10	10	10	Home Garden	1118.61209198...	24640.2263927...	0.02	NULL
11	11	11	Home Garden	1201.28654152...	23049.3427363...	0.02	NULL
12	12	12	Forest	21616.1077983...	10599354.3021...	10.60	NULL
13	13	13	Home Garden	852.31742858300	18421.4767636...	0.02	NULL
14	14	14	Forest	17135.8491440...	5175386.43554...	5.18	NULL
15	15	15	Mixed Crop	1137.08316880...	32271.8629505...	0.03	NULL
16	16	16	Paddy	1350.51420227...	57605.5593162...	0.06	NULL
17	17	17	Home Garden	1845.31383046...	79789.0108553...	0.08	NULL
18	18	18	Home Garden	1733.71833854...	138862.127201...	0.14	NULL
19	19	19	Home Garden	1445.51485434...	67613.2591164...	0.07	NULL
20	20	20	Home Garden	2270.19326061...	58704.0006069...	0.06	NULL
21	21	21	Mixed Crop	1326.44501681...	40951.2535784...	0.04	NULL
22	22	22	Agricultural Land	1969.55971315...	79753.4005574...	0.08	NULL
23	23	23	Home Garden	1113.24129280...	49153.8418755...	0.05	NULL

4.12 The field calculator will open. Click on the “**Update existing field**” and make sure to display the “✓” mark on that. Through this, an existing field in the attribute table will be updated.

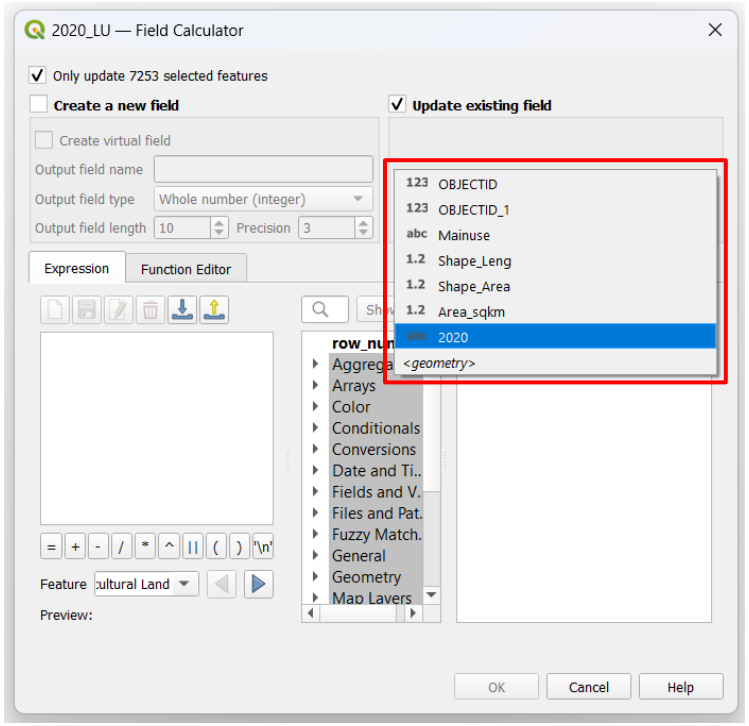


4.13 Now, we have to select the existing field that we want to update.

- For that, click on this expandable tab.



- Then select "**2020**".



After selecting the field, you can use the following expression to add "Agricultural Lands" to the selected field at once. Then the newly added field of all the land uses we selected above will be updated as "Agricultural Lands" on the attribute table.

- Once done entering this expression, you can click on "**OK**" to proceed. This expression contains,
  Concat ("Name of the existing field", 'The value')
- You should correctly type this expression using single commas and double commas. If you do not enter this correctly, you will have an error message.

- The expression,

  Concat (“2020”, ‘Agricultural Lands’)

- **Double Quotes (" "):** Used for field names to reference the data in those fields.

- **Single Quotes (' '):** Used for literal strings to include fixed text values.

If you want to deselect all the selected features, you can use the below tool.

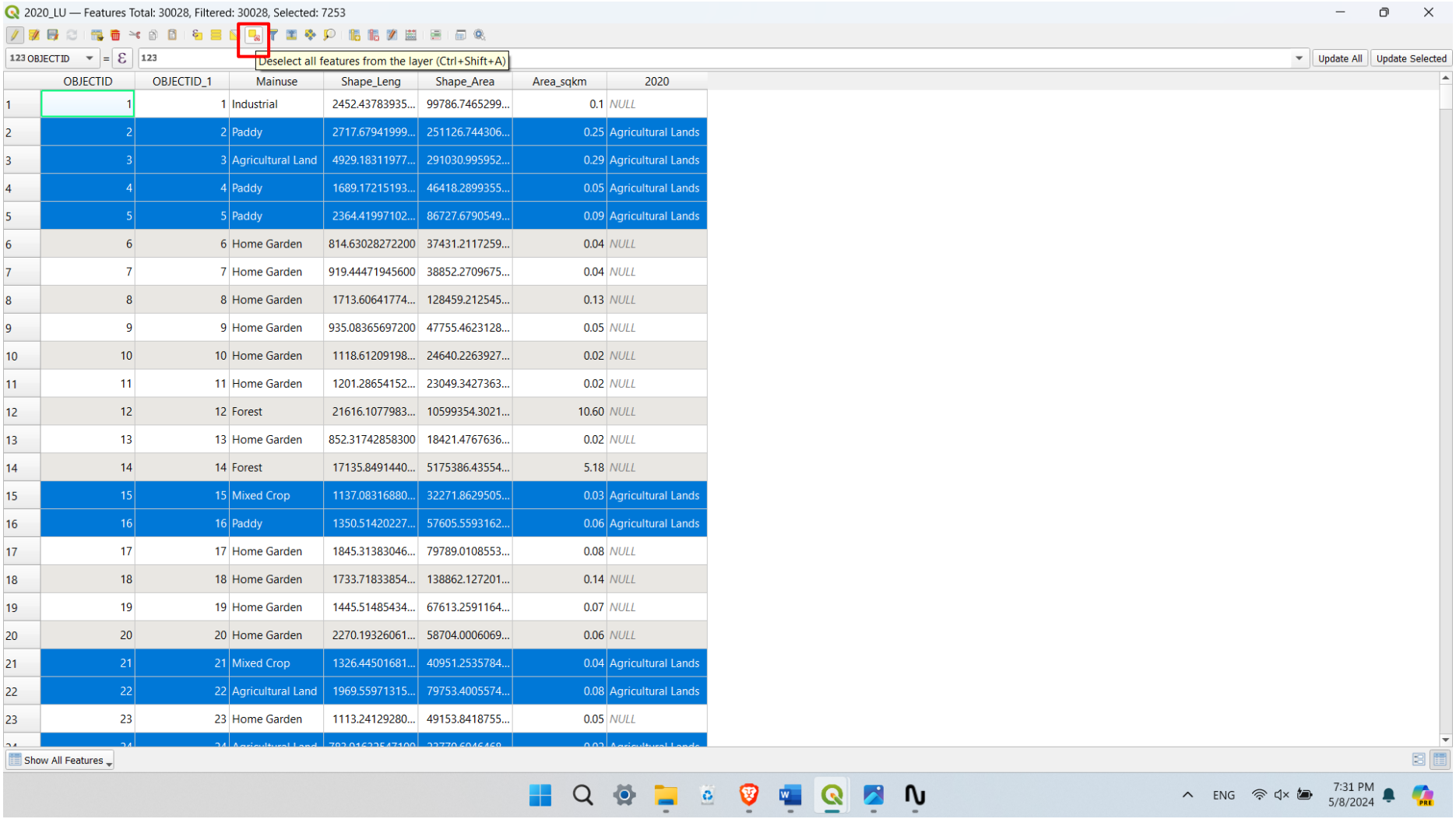
- Now, the values are added to the attribute table.

2020_LU — Features Total: 30028, Filtered: 30028, Selected: 7253

123 OBJECTID = ε 123

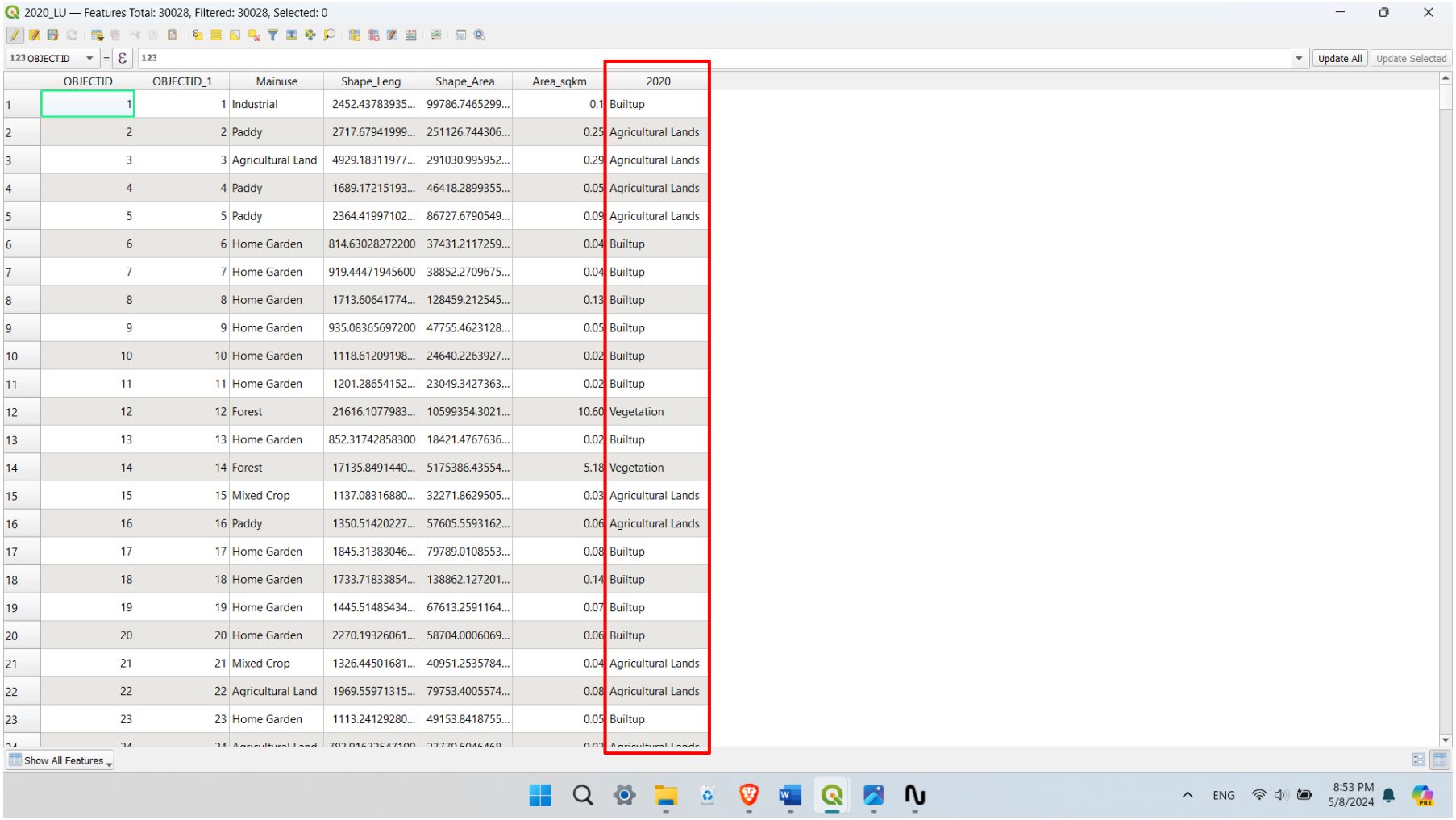
	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm	2020
1	1	1	Industrial	2452.43783935...	99786.7465299...	0.1	NULL
2	2	2	Paddy	2717.67941999...	251126.744306...	0.25	Agricultural Lands
3	3	3	Agricultural Land	4929.18311977...	291030.995952...	0.29	Agricultural Lands
4	4	4	Paddy	1689.17215193...	46418.2899355...	0.05	Agricultural Lands
5	5	5	Paddy	2364.41997102...	86727.6790549...	0.09	Agricultural Lands
6	6	6	Home Garden	814.63028272200	37431.2117259...	0.04	NULL
7	7	7	Home Garden	919.44471945600	38852.2709675...	0.04	NULL
8	8	8	Home Garden	1713.60641774...	128459.212545...	0.13	NULL
9	9	9	Home Garden	935.08365697200	47755.4623128...	0.05	NULL
10	10	10	Home Garden	1118.61209198...	24640.2263927...	0.02	NULL
11	11	11	Home Garden	1201.28654152...	23049.3427363...	0.02	NULL
12	12	12	Forest	21616.1077983...	10599354.3021...	10.60	NULL
13	13	13	Home Garden	852.31742858300	18421.4767636...	0.02	NULL
14	14	14	Forest	17135.8491440...	5175386.43554...	5.18	NULL
15	15	15	Mixed Crop	1137.08316880...	32271.8629505...	0.03	Agricultural Lands
16	16	16	Paddy	1350.51420227...	57605.5593162...	0.06	Agricultural Lands
17	17	17	Home Garden	1845.31383046...	79789.0108553...	0.08	NULL
18	18	18	Home Garden	1733.71833854...	138862.127201...	0.14	NULL
19	19	19	Home Garden	1445.51485434...	67613.2591164...	0.07	NULL
20	20	20	Home Garden	2270.19326061...	58704.0006069...	0.06	NULL
21	21	21	Mixed Crop	1326.44501681...	40951.2535784...	0.04	Agricultural Lands
22	22	22	Agricultural Land	1969.55971315...	79753.4005574...	0.08	Agricultural Lands
23	23	23	Home Garden	1113.24129280...	49153.8418755...	0.05	NULL

Show All Features



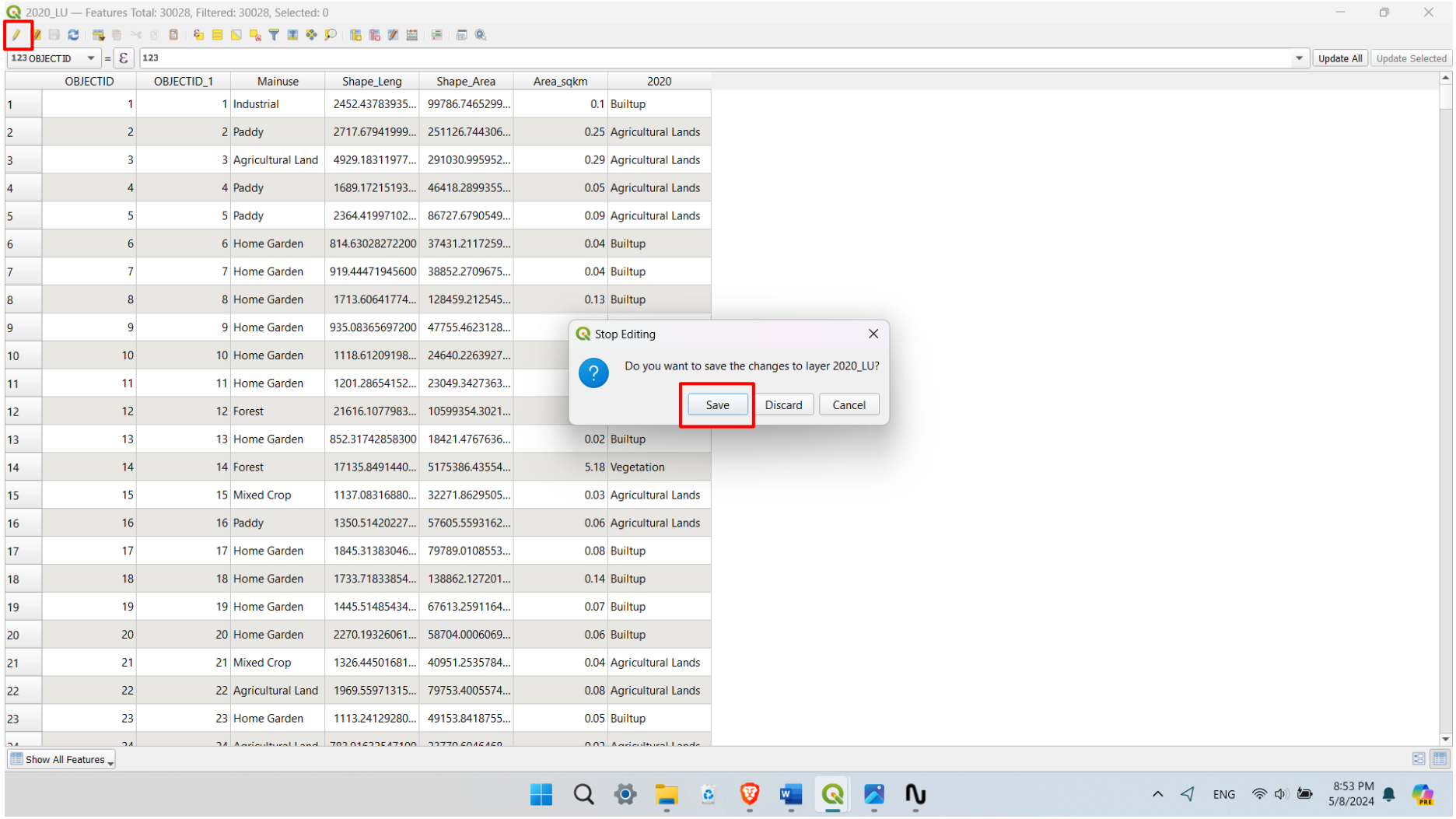
	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm	2020
1	1	1	Industrial	2452.43783935...	99786.7465299...	0.1	NULL
2	2	2	Paddy	2717.67941999...	251126.744306...	0.25	Agricultural Lands
3	3	3	Agricultural Land	4929.18311977...	291030.995952...	0.29	Agricultural Lands
4	4	4	Paddy	1689.17215193...	46418.2899355...	0.05	Agricultural Lands
5	5	5	Paddy	2364.41997102...	86727.6790549...	0.09	Agricultural Lands
6	6	6	Home Garden	814.63028272200	37431.2117259...	0.04	NULL
7	7	7	Home Garden	919.44471945600	38852.2709675...	0.04	NULL
8	8	8	Home Garden	1713.60641774...	128459.212545...	0.13	NULL
9	9	9	Home Garden	935.08365697200	47755.4623128...	0.05	NULL
10	10	10	Home Garden	1118.61209198...	24640.2263927...	0.02	NULL
11	11	11	Home Garden	1201.28654152...	23049.3427363...	0.02	NULL
12	12	12	Forest	21616.1077983...	10599354.3021...	10.60	NULL
13	13	13	Home Garden	852.31742858300	18421.4767636...	0.02	NULL
14	14	14	Forest	17135.8491440...	5175386.43554...	5.18	NULL
15	15	15	Mixed Crop	1137.08316880...	32271.8629505...	0.03	Agricultural Lands
16	16	16	Paddy	1350.51420227...	57605.5593162...	0.06	Agricultural Lands
17	17	17	Home Garden	1845.31383046...	79789.0108553...	0.08	NULL
18	18	18	Home Garden	1733.71833854...	138862.127201...	0.14	NULL
19	19	19	Home Garden	1445.51485434...	67613.2591164...	0.07	NULL
20	20	20	Home Garden	2270.19326061...	58704.0006069...	0.06	NULL
21	21	21	Mixed Crop	1326.44501681...	40951.2535784...	0.04	Agricultural Lands
22	22	22	Agricultural Land	1969.55971315...	79753.4005574...	0.08	Agricultural Lands
23	23	23	Home Garden	1113.24129280...	49153.8418755...	0.05	NULL

By following the same steps as above, the attribute table should also be updated for the main land use categories that we have selected namely **built-up areas, vegetation,** and **water bodies**. (As shown in Table 3) Once this "2020" field in the attribute table is completely prepared, it will look like this.



	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm	2020
1	1	1	Industrial	2452.43783935...	99786.7465299...	0.1	Builtup
2	2	2	Paddy	2717.67941999...	251126.744306...	0.25	Agricultural Lands
3	3	3	Agricultural Land	4929.18311977...	291030.995952...	0.29	Agricultural Lands
4	4	4	Paddy	1689.17215193...	46418.2899355...	0.05	Agricultural Lands
5	5	5	Paddy	2364.41997102...	86727.6790549...	0.09	Agricultural Lands
6	6	6	Home Garden	814.63028272200	37431.2117259...	0.04	Builtup
7	7	7	Home Garden	919.44471945600	38852.2709675...	0.04	Builtup
8	8	8	Home Garden	1713.60641774...	128459.212545...	0.13	Builtup
9	9	9	Home Garden	935.08365697200	47755.4623128...	0.05	Builtup
10	10	10	Home Garden	1118.61209198...	24640.2263927...	0.02	Builtup
11	11	11	Home Garden	1201.28654152...	23049.3427363...	0.02	Builtup
12	12	12	Forest	21616.1077983...	10599354.3021...	10.60	Vegetation
13	13	13	Home Garden	852.31742858300	18421.4767636...	0.02	Builtup
14	14	14	Forest	17135.8491440...	5175386.43554...	5.18	Vegetation
15	15	15	Mixed Crop	1137.08316880...	32271.8629505...	0.03	Agricultural Lands
16	16	16	Paddy	1350.51420227...	57605.5593162...	0.06	Agricultural Lands
17	17	17	Home Garden	1845.31383046...	79789.0108553...	0.08	Builtup
18	18	18	Home Garden	1733.71833854...	138862.127201...	0.14	Builtup
19	19	19	Home Garden	1445.51485434...	67613.2591164...	0.07	Builtup
20	20	20	Home Garden	2270.19326061...	58704.0006069...	0.06	Builtup
21	21	21	Mixed Crop	1326.44501681...	40951.2535784...	0.04	Agricultural Lands
22	22	22	Agricultural Land	1969.55971315...	79753.4005574...	0.08	Agricultural Lands
23	23	23	Home Garden	1113.24129280...	49153.8418755...	0.05	Builtup

4.14 After adding these data successfully, click on the pencil icon again and **save** the edits.



	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm	2020
1	1	1	Industrial	2452.43783935...	99786.7465299...	0.1	Builtup
2	2	2	Paddy	2717.67941999...	251126.744306...	0.25	Agricultural Lands
3	3	3	Agricultural Land	4929.18311977...	291030.995952...	0.29	Agricultural Lands
4	4	4	Paddy	1689.17215193...	46418.2899355...	0.05	Agricultural Lands
5	5	5	Paddy	2364.41997102...	86727.6790549...	0.09	Agricultural Lands
6	6	6	Home Garden	814.63028272200	37431.2117259...	0.04	Builtup
7	7	7	Home Garden	919.44471945600	38852.2709675...	0.04	Builtup
8	8	8	Home Garden	1713.60641774...	128459.212545...	0.13	Builtup
9	9	9	Home Garden	935.08365697200	47755.4623128...		
10	10	10	Home Garden	1118.61209198...	24640.2263927...		
11	11	11	Home Garden	1201.28654152...	23049.3427363...		
12	12	12	Forest	21616.1077983...	10599354.3021...		
13	13	13	Home Garden	852.31742858300	18421.4767636...	0.02	Builtup
14	14	14	Forest	17135.8491440...	5175386.43554...	5.18	Vegetation
15	15	15	Mixed Crop	1137.08316880...	32271.8629505...	0.03	Agricultural Lands
16	16	16	Paddy	1350.51420227...	57605.5593162...	0.06	Agricultural Lands
17	17	17	Home Garden	1845.31383046...	79789.0108553...	0.08	Builtup
18	18	18	Home Garden	1733.71833854...	138862.127201...	0.14	Builtup
19	19	19	Home Garden	1445.51485434...	67613.2591164...	0.07	Builtup
20	20	20	Home Garden	2270.19326061...	58704.0006069...	0.06	Builtup
21	21	21	Mixed Crop	1326.44501681...	40951.2535784...	0.04	Agricultural Lands
22	22	22	Agricultural Land	1969.55971315...	79753.4005574...	0.08	Agricultural Lands
23	23	23	Home Garden	1113.24129280...	49153.8418755...	0.05	Builtup

Step 05 - Rasterization of the layers

When we convert a vector layer to a raster layer in QGIS, the choice of field for rasterization is crucial for accurate representation. The selected field determines the values assigned to each raster cell, influencing the interpretation of the resulting raster layer. It's essential to note that string-type fields, containing text or categorical labels, cannot be selected for rasterization. This limitation arises because rasterization requires numeric values to represent information in raster cells effectively. Numeric attributes, such as integer fields for categorical data and floating-point or double fields for continuous or decimal data, are suitable choices for rasterization.

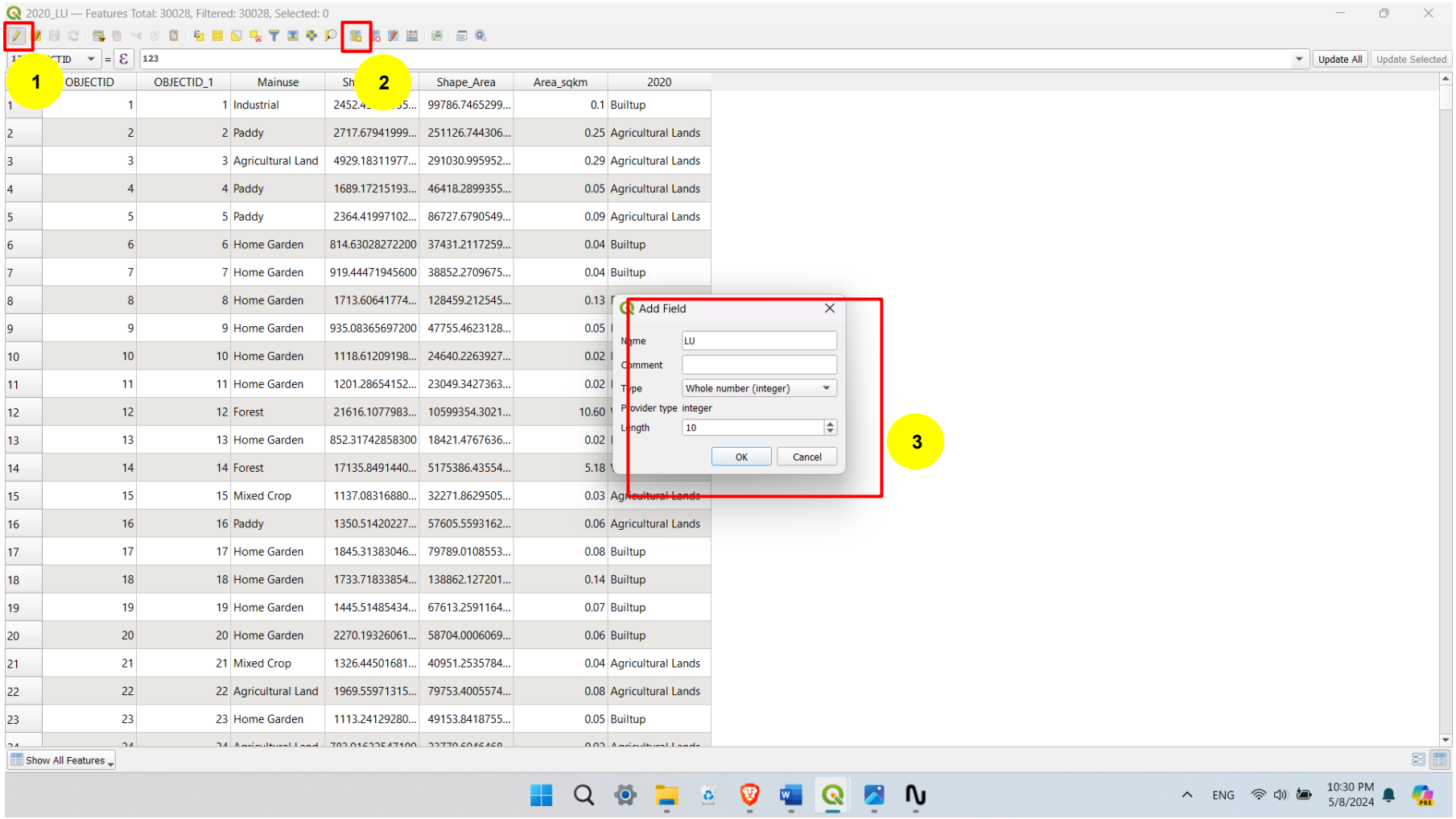
For categorical data, such as land use categories, an integer field with class codes (e.g., 1 for urban, 2 for forest) is ideal. Conversely, continuous data, like elevation, is best represented using a floating-point field with actual elevation values. When converting vector layers with string fields, it's advisable to create new numeric fields, perhaps using the Field Calculator tool, to store relevant quantitative information before rasterization. By selecting the appropriate field type, we can ensure the meaningful interpretation of the resulting raster layer, facilitating accurate analysis and visualization of spatial data.

Accordingly, by adding another field in the same attribute table that we prepared, we should give a numeric value for the 4 main land use categories. Let's give numerical values for land uses as follows.

Land Use Category	Numeric Value
Built-up Areas	1
Agricultural Lands	2
Vegetation	3
Water Bodies	4

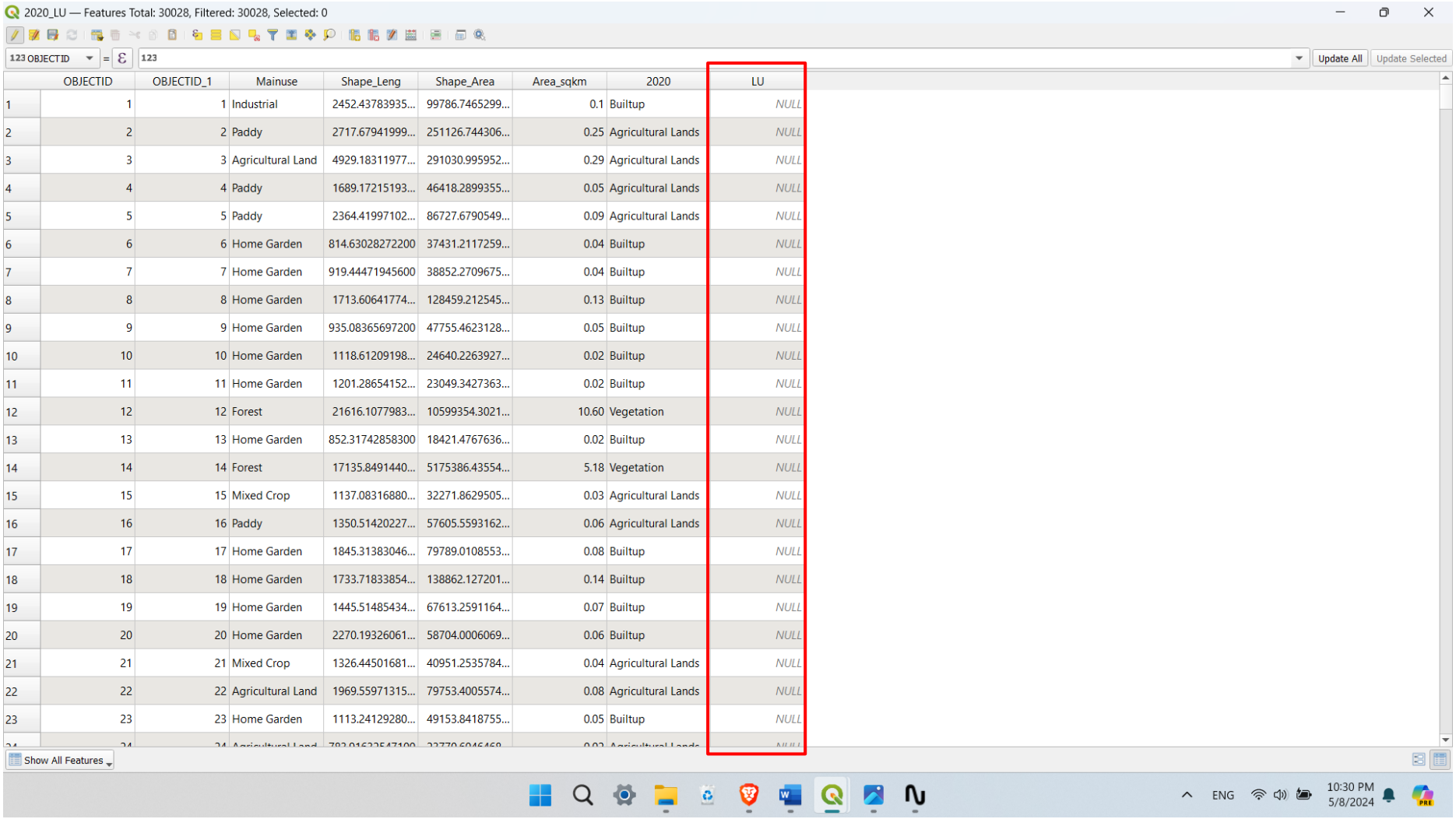
Table 4 — Numerical values for the land use categories

5.1 Turn on the editable mode of the layer by clicking the “**Toggle editing mode**” tool. Then, add a new field as before. Name it as “**LU**” and set the type as a numeric type. I set here the type “**Whole number (integer)**” and the length as “**10**”.



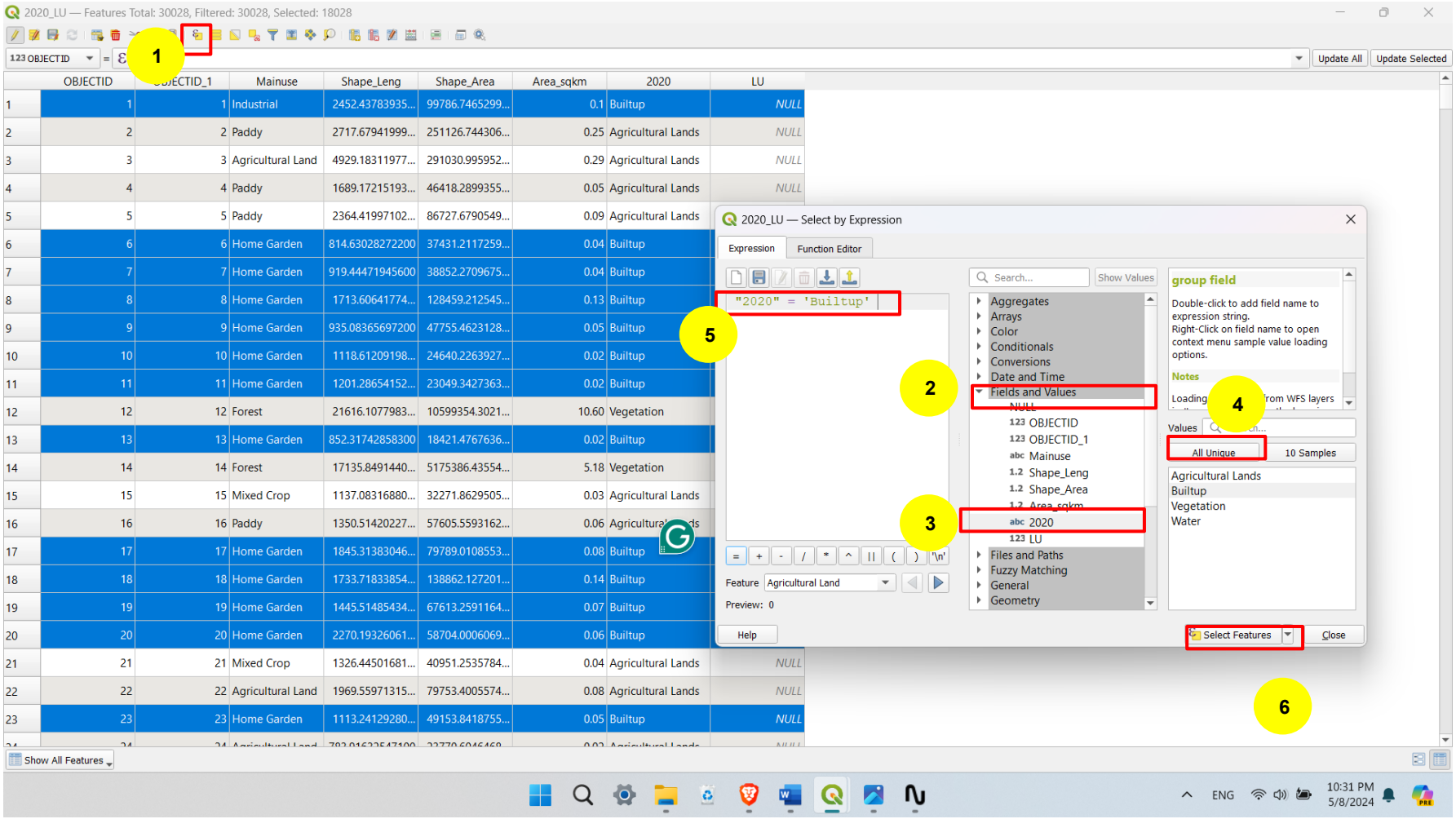
	OBJECTID	OBJECTID_1	Mainuse	Sh	Shape_Area	Area_sqkm	2020
1	1	1	Industrial	2452.4...	99786.7465299...	0.1	Builtup
2	2	2	Paddy	2717.67941999...	251126.744306...	0.25	Agricultural Lands
3	3	3	Agricultural Land	4929.18311977...	291030.995952...	0.29	Agricultural Lands
4	4	4	Paddy	1689.17215193...	46418.2899355...	0.05	Agricultural Lands
5	5	5	Paddy	2364.41997102...	86727.6790549...	0.09	Agricultural Lands
6	6	6	Home Garden	814.63028272200	37431.2117259...	0.04	Builtup
7	7	7	Home Garden	919.44471945600	38852.2709675...	0.04	Builtup
8	8	8	Home Garden	1713.60641774...	128459.212545...	0.13	
9	9	9	Home Garden	935.08365697200	47755.4623128...	0.05	
10	10	10	Home Garden	1118.61209198...	24640.2263927...	0.02	
11	11	11	Home Garden	1201.28654152...	23049.3427363...	0.02	
12	12	12	Forest	21616.1077983...	10599354.3021...	10.60	
13	13	13	Home Garden	852.31742858300	18421.4767636...	0.02	
14	14	14	Forest	17135.8491440...	5175386.43554...	5.18	
15	15	15	Mixed Crop	1137.08316880...	32271.8629505...	0.03	Agricultural Lands
16	16	16	Paddy	1350.51420227...	57605.5593162...	0.06	Agricultural Lands
17	17	17	Home Garden	1845.31383046...	79789.0108553...	0.08	Builtup
18	18	18	Home Garden	1733.71833854...	138862.127201...	0.14	Builtup
19	19	19	Home Garden	1445.51485434...	67613.2591164...	0.07	Builtup
20	20	20	Home Garden	2270.19326061...	58704.0006069...	0.06	Builtup
21	21	21	Mixed Crop	1326.44501681...	40951.2535784...	0.04	Agricultural Lands
22	22	22	Agricultural Land	1969.55971315...	79753.4005574...	0.08	Agricultural Lands
23	23	23	Home Garden	1113.24129280...	49153.8418755...	0.05	Builtup

5.2 The newly added field will be shown as follows.

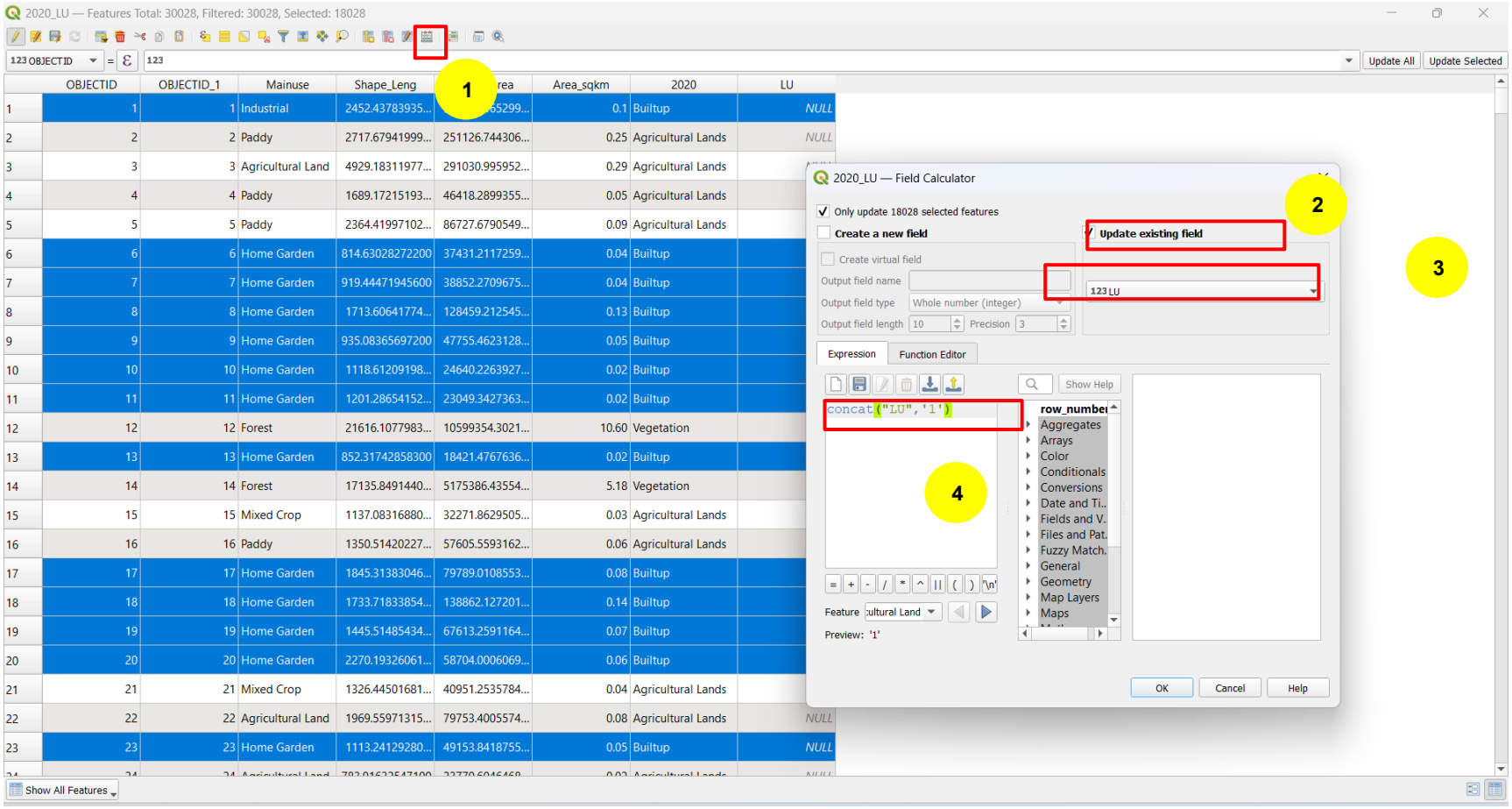


	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm	2020	LU
1	1	1	Industrial	2452.43783935...	99786.7465299...	0.1	Builtup	NULL
2	2	2	Paddy	2717.67941999...	251126.744306...	0.25	Agricultural Lands	NULL
3	3	3	Agricultural Land	4929.18311977...	291030.995952...	0.29	Agricultural Lands	NULL
4	4	4	Paddy	1689.17215193...	46418.2899355...	0.05	Agricultural Lands	NULL
5	5	5	Paddy	2364.41997102...	86727.6790549...	0.09	Agricultural Lands	NULL
6	6	6	Home Garden	814.63028272200	37431.2117259...	0.04	Builtup	NULL
7	7	7	Home Garden	919.44471945600	38852.2709675...	0.04	Builtup	NULL
8	8	8	Home Garden	1713.60641774...	128459.212545...	0.13	Builtup	NULL
9	9	9	Home Garden	935.08365697200	47755.4623128...	0.05	Builtup	NULL
10	10	10	Home Garden	1118.61209198...	24640.2263927...	0.02	Builtup	NULL
11	11	11	Home Garden	1201.28654152...	23049.3427363...	0.02	Builtup	NULL
12	12	12	Forest	21616.1077983...	10599354.3021...	10.60	Vegetation	NULL
13	13	13	Home Garden	852.31742858300	18421.4767636...	0.02	Builtup	NULL
14	14	14	Forest	17135.8491440...	5175386.43554...	5.18	Vegetation	NULL
15	15	15	Mixed Crop	1137.08316880...	32271.8629505...	0.03	Agricultural Lands	NULL
16	16	16	Paddy	1350.51420227...	57605.5593162...	0.06	Agricultural Lands	NULL
17	17	17	Home Garden	1845.31383046...	79789.0108553...	0.08	Builtup	NULL
18	18	18	Home Garden	1733.71833854...	138862.127201...	0.14	Builtup	NULL
19	19	19	Home Garden	1445.51485434...	67613.2591164...	0.07	Builtup	NULL
20	20	20	Home Garden	2270.19326061...	58704.0006069...	0.06	Builtup	NULL
21	21	21	Mixed Crop	1326.44501681...	40951.2535784...	0.04	Agricultural Lands	NULL
22	22	22	Agricultural Land	1969.55971315...	79753.4005574...	0.08	Agricultural Lands	NULL
23	23	23	Home Garden	1113.24129280...	49153.8418755...	0.05	Builtup	NULL

5.3 Open the “**Select by Expression**” and expand the “**Fields and Values**”. Then, double-click on “**2020**” and type “**=**”. After that, click on “**All Unique**” and double-click on a land use category. Then the expression will be entered as follows. Finally, click on “**Select Features**”.

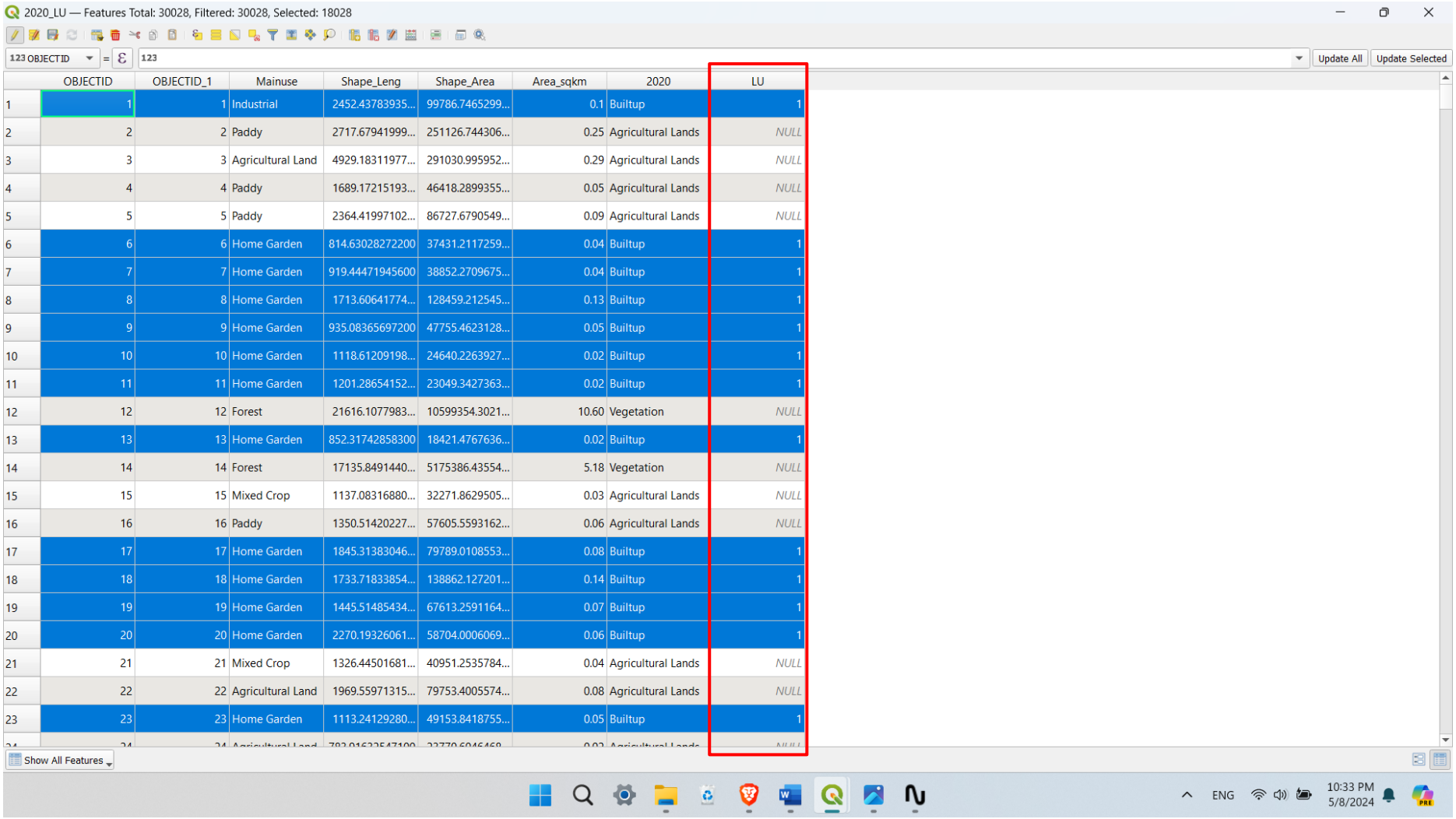


5.4 The selected features are displayed in blue color. Now, open the "**Field Calculator**" and update the existing field "**LU**", according to the numerical values that we introduced under **Table 4**. Use the expression as **concat ("LU", '1')** for the built-up areas. According to the Table 4, change the numeric value in this expression.



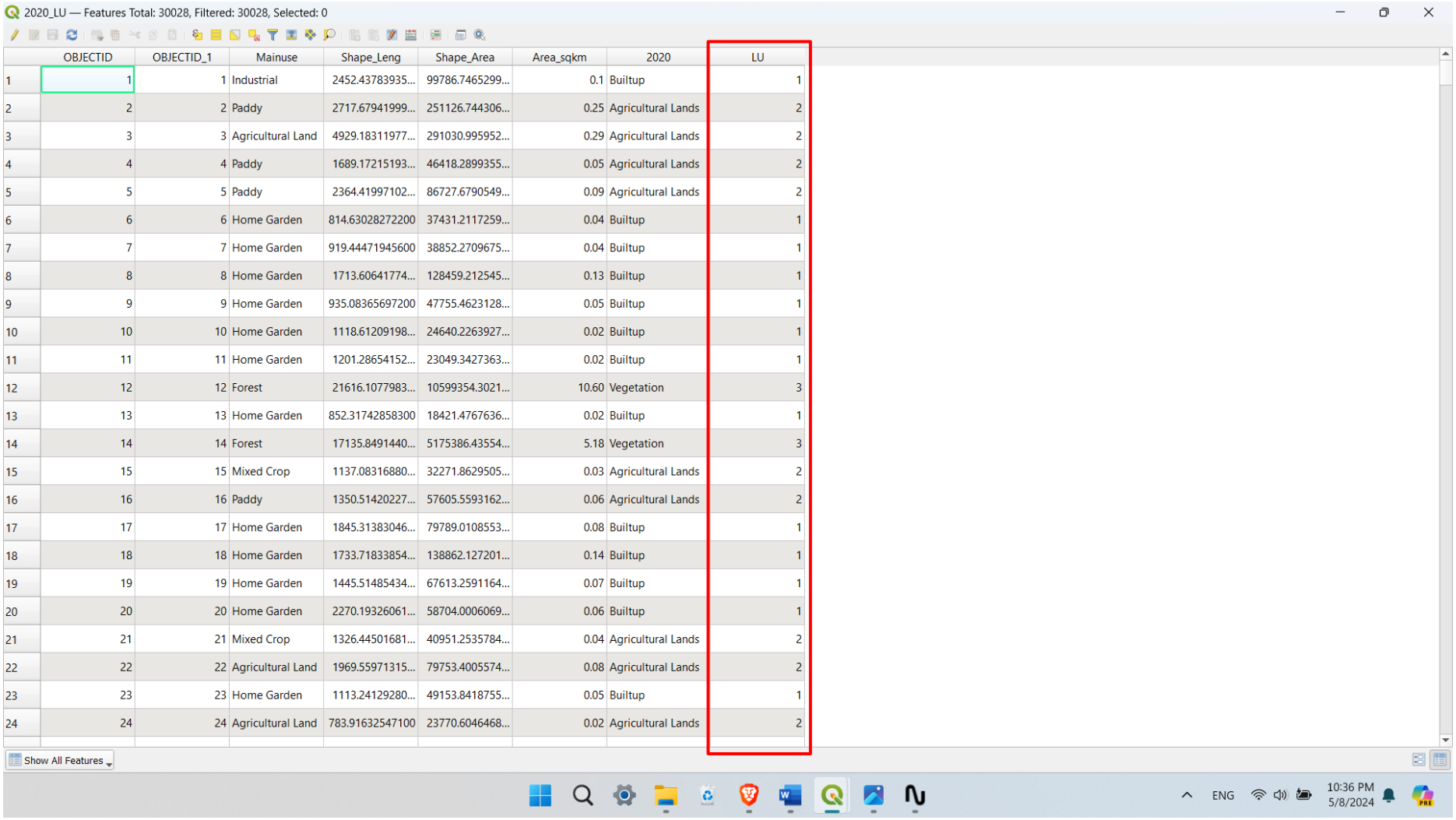
	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	Area_sqkm	2020	LU
1	1	1	Industrial	2452.43783935...	0.1	Builtup	NULL
2	2	2	Paddy	2717.67941999...	0.25	Agricultural Lands	NULL
3	3	3	Agricultural Land	4929.18311977...	0.29	Agricultural Lands	
4	4	4	Paddy	1689.17215193...	0.05	Agricultural Lands	
5	5	5	Paddy	2364.41997102...	0.09	Agricultural Lands	
6	6	6	Home Garden	814.63028272200	0.04	Builtup	
7	7	7	Home Garden	919.44471945600	0.04	Builtup	
8	8	8	Home Garden	1713.60641774...	0.13	Builtup	
9	9	9	Home Garden	935.08365697200	0.05	Builtup	
10	10	10	Home Garden	1118.61209198...	0.02	Builtup	
11	11	11	Home Garden	1201.28654152...	0.02	Builtup	
12	12	12	Forest	21616.1077983...	10.60	Vegetation	
13	13	13	Home Garden	852.31742858300	0.02	Builtup	
14	14	14	Forest	17135.8491440...	5.18	Vegetation	
15	15	15	Mixed Crop	1137.08316880...	0.03	Agricultural Lands	
16	16	16	Paddy	1350.51420227...	0.06	Agricultural Lands	
17	17	17	Home Garden	1845.31383046...	0.08	Builtup	
18	18	18	Home Garden	1733.71833854...	0.14	Builtup	
19	19	19	Home Garden	1445.51485434...	0.07	Builtup	
20	20	20	Home Garden	2270.19326061...	0.06	Builtup	
21	21	21	Mixed Crop	1326.44501681...	0.04	Agricultural Lands	
22	22	22	Agricultural Land	1969.55971315...	0.08	Agricultural Lands	NULL
23	23	23	Home Garden	1113.24129280...	0.05	Builtup	NULL

Numeric values are added to this field as follows.



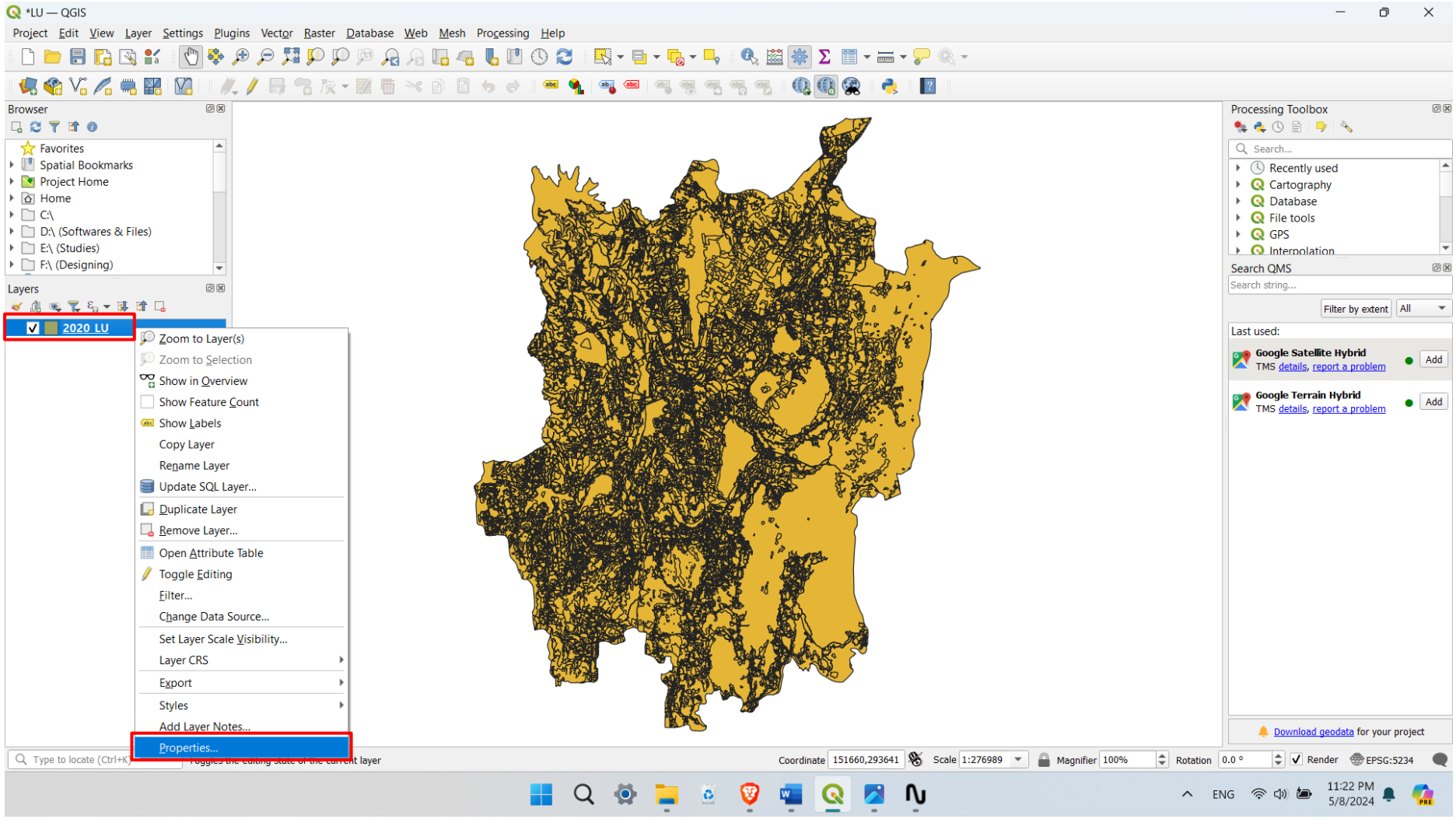
	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm	2020	LU
1	1	1	Industrial	2452.43783935...	99786.7465299...	0.1	Builtup	1
2	2	2	Paddy	2717.67941999...	251126.744306...	0.25	Agricultural Lands	NULL
3	3	3	Agricultural Land	4929.18311977...	291030.995952...	0.29	Agricultural Lands	NULL
4	4	4	Paddy	1689.17215193...	46418.2899355...	0.05	Agricultural Lands	NULL
5	5	5	Paddy	2364.41997102...	86727.6790549...	0.09	Agricultural Lands	NULL
6	6	6	Home Garden	814.63028272200	37431.2117259...	0.04	Builtup	1
7	7	7	Home Garden	919.44471945600	38852.2709675...	0.04	Builtup	1
8	8	8	Home Garden	1713.60641774...	128459.212545...	0.13	Builtup	1
9	9	9	Home Garden	935.08365697200	47755.4623128...	0.05	Builtup	1
10	10	10	Home Garden	1118.61209198...	24640.2263927...	0.02	Builtup	1
11	11	11	Home Garden	1201.28654152...	23049.3427363...	0.02	Builtup	1
12	12	12	Forest	21616.1077983...	10599354.3021...	10.60	Vegetation	NULL
13	13	13	Home Garden	852.31742858300	18421.4767636...	0.02	Builtup	1
14	14	14	Forest	17135.8491440...	5175386.43554...	5.18	Vegetation	NULL
15	15	15	Mixed Crop	1137.08316880...	32271.8629505...	0.03	Agricultural Lands	NULL
16	16	16	Paddy	1350.51420227...	57605.5593162...	0.06	Agricultural Lands	NULL
17	17	17	Home Garden	1845.31383046...	79789.0108553...	0.08	Builtup	1
18	18	18	Home Garden	1733.71833854...	138862.127201...	0.14	Builtup	1
19	19	19	Home Garden	1445.51485434...	67613.2591164...	0.07	Builtup	1
20	20	20	Home Garden	2270.19326061...	58704.0006069...	0.06	Builtup	1
21	21	21	Mixed Crop	1326.44501681...	40951.2535784...	0.04	Agricultural Lands	NULL
22	22	22	Agricultural Land	1969.55971315...	79753.4005574...	0.08	Agricultural Lands	NULL
23	23	23	Home Garden	1113.24129280...	49153.8418755...	0.05	Builtup	1

5.5 Then, follow the same steps and add values for other land use categories as well. As the final step, save the edits.

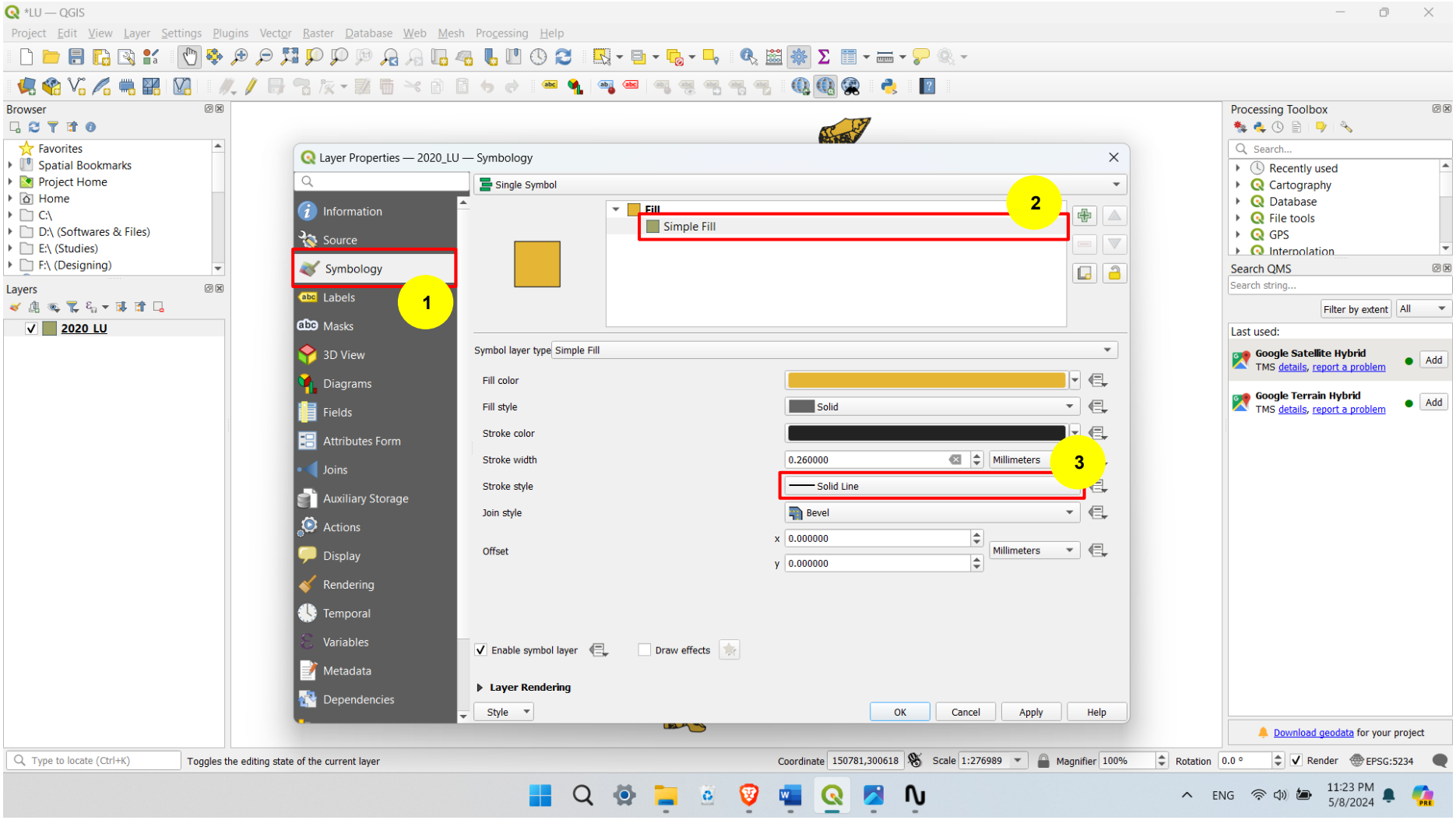


	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm	2020	LU
1	1	1	Industrial	2452.43783935...	99786.7465299...	0.1	Builtup	1
2	2	2	Paddy	2717.67941999...	251126.744306...	0.25	Agricultural Lands	2
3	3	3	Agricultural Land	4929.18311977...	291030.995952...	0.29	Agricultural Lands	2
4	4	4	Paddy	1689.17215193...	46418.2899355...	0.05	Agricultural Lands	2
5	5	5	Paddy	2364.41997102...	86727.6790549...	0.09	Agricultural Lands	2
6	6	6	Home Garden	814.63028272200	37431.2117259...	0.04	Builtup	1
7	7	7	Home Garden	919.44471945600	38852.2709675...	0.04	Builtup	1
8	8	8	Home Garden	1713.60641774...	128459.212545...	0.13	Builtup	1
9	9	9	Home Garden	935.08365697200	47755.4623128...	0.05	Builtup	1
10	10	10	Home Garden	1118.61209198...	24640.2263927...	0.02	Builtup	1
11	11	11	Home Garden	1201.28654152...	23049.3427363...	0.02	Builtup	1
12	12	12	Forest	21616.1077983...	10599354.3021...	10.60	Vegetation	3
13	13	13	Home Garden	852.31742858300	18421.4767636...	0.02	Builtup	1
14	14	14	Forest	17135.8491440...	5175386.43554...	5.18	Vegetation	3
15	15	15	Mixed Crop	1137.08316880...	32271.8629505...	0.03	Agricultural Lands	2
16	16	16	Paddy	1350.51420227...	57605.5593162...	0.06	Agricultural Lands	2
17	17	17	Home Garden	1845.31383046...	79789.0108553...	0.08	Builtup	1
18	18	18	Home Garden	1733.71833854...	138862.127201...	0.14	Builtup	1
19	19	19	Home Garden	1445.51485434...	67613.2591164...	0.07	Builtup	1
20	20	20	Home Garden	2270.19326061...	58704.0006069...	0.06	Builtup	1
21	21	21	Mixed Crop	1326.44501681...	40951.2535784...	0.04	Agricultural Lands	2
22	22	22	Agricultural Land	1969.55971315...	79753.4005574...	0.08	Agricultural Lands	2
23	23	23	Home Garden	1113.24129280...	49153.8418755...	0.05	Builtup	1
24	24	24	Agricultural Land	783.91632547100	23770.6046468...	0.02	Agricultural Lands	2

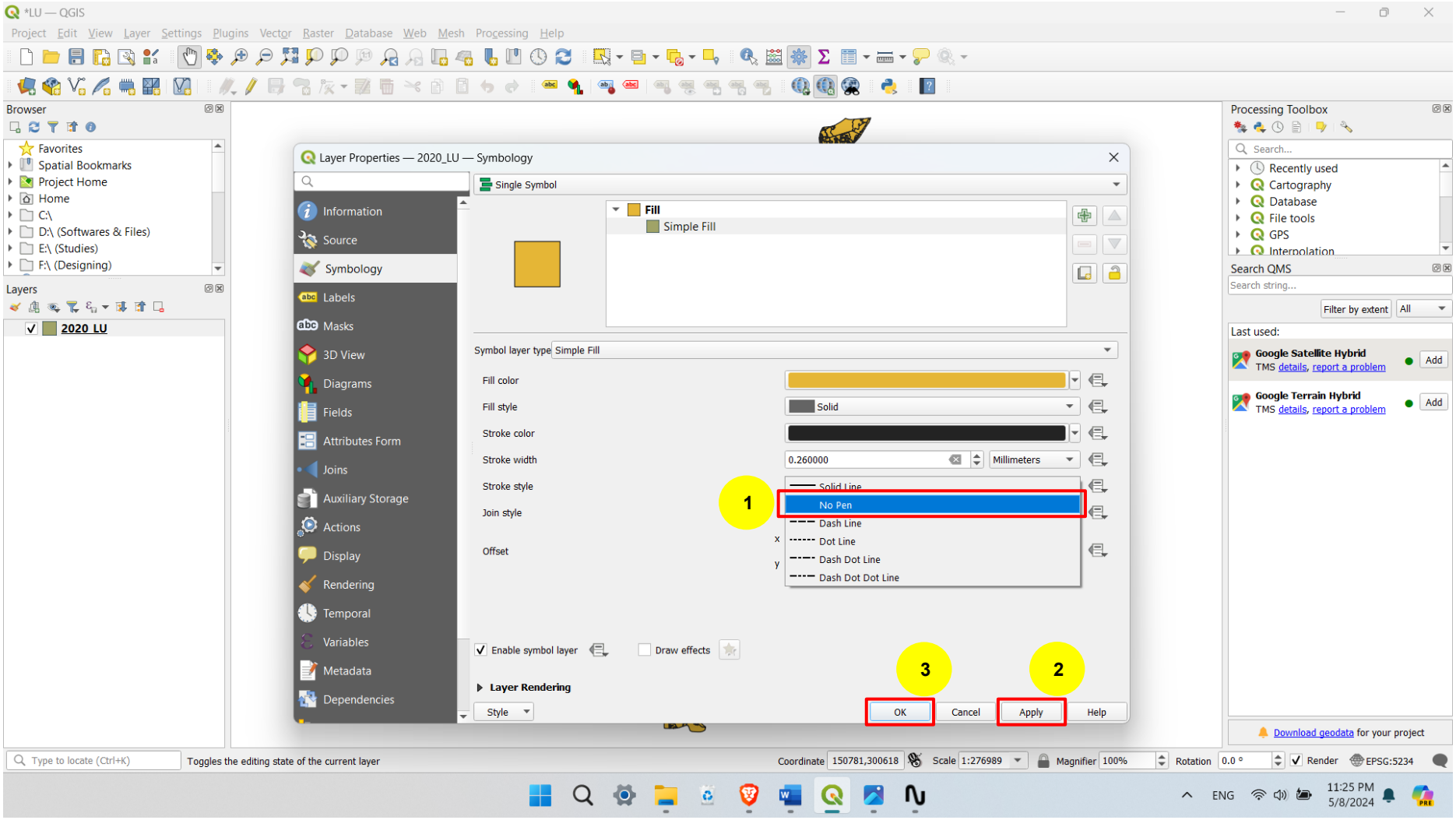
5.6 After saving the edits, right-click on the layer and open the layer properties.



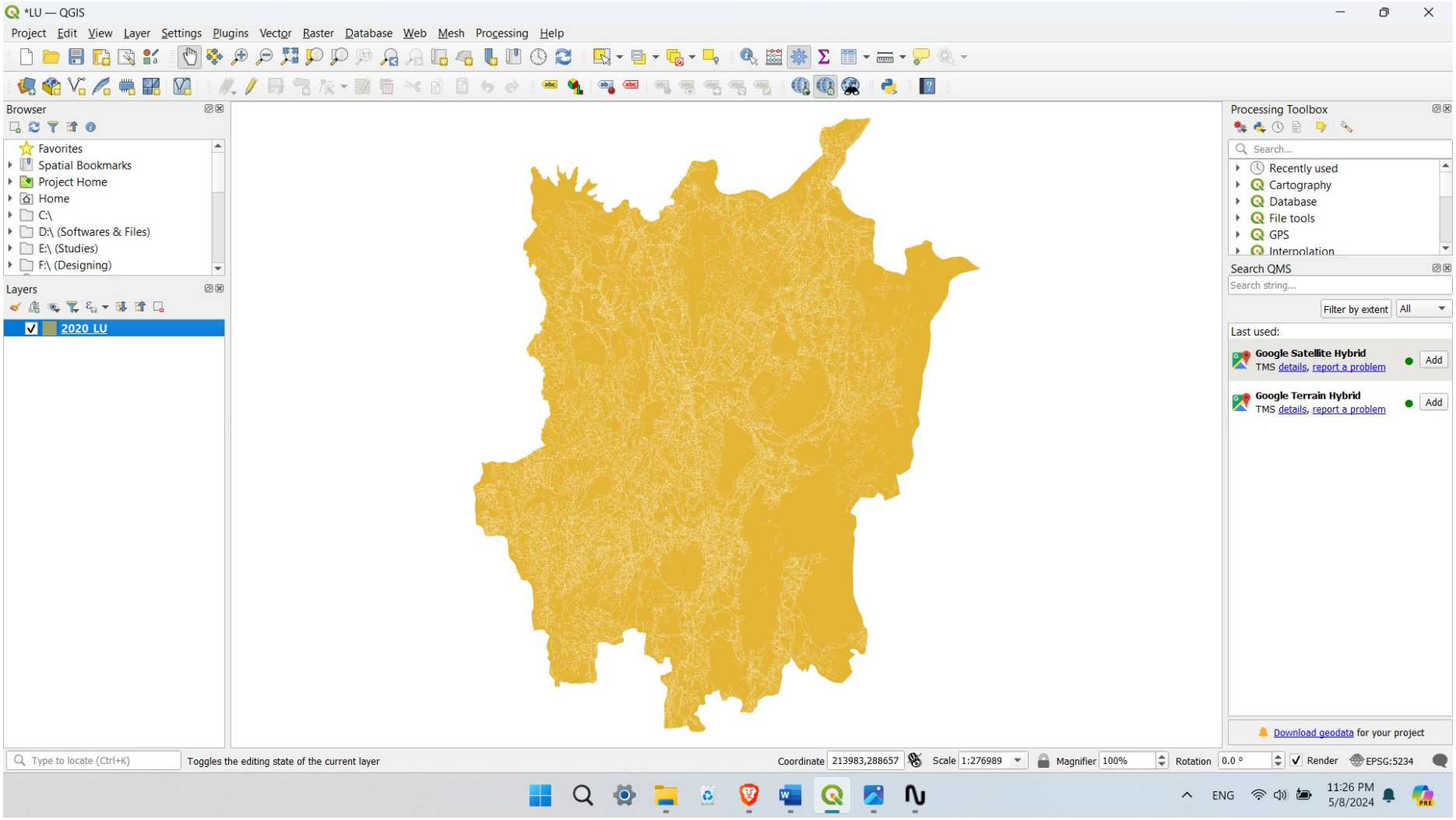
5.7 Go to the “**Symbology**” properties. Next, click on “**Simple Fill**”. Then expand the “**Stroke style**”.



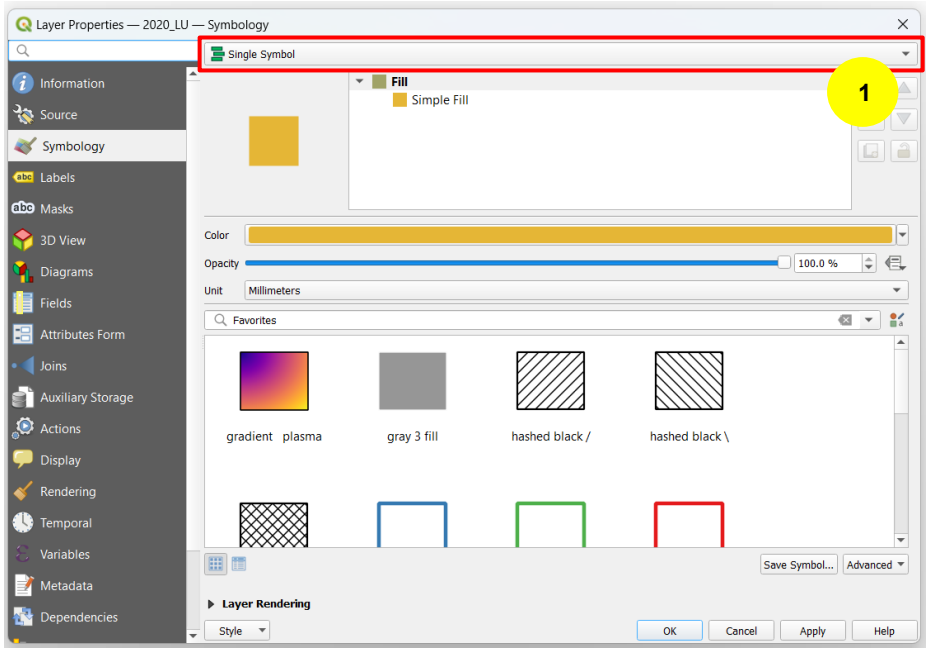
5.8 Select “**No Pen**” from the expanded list. After that, click on “**Apply**” and “**OK**”.

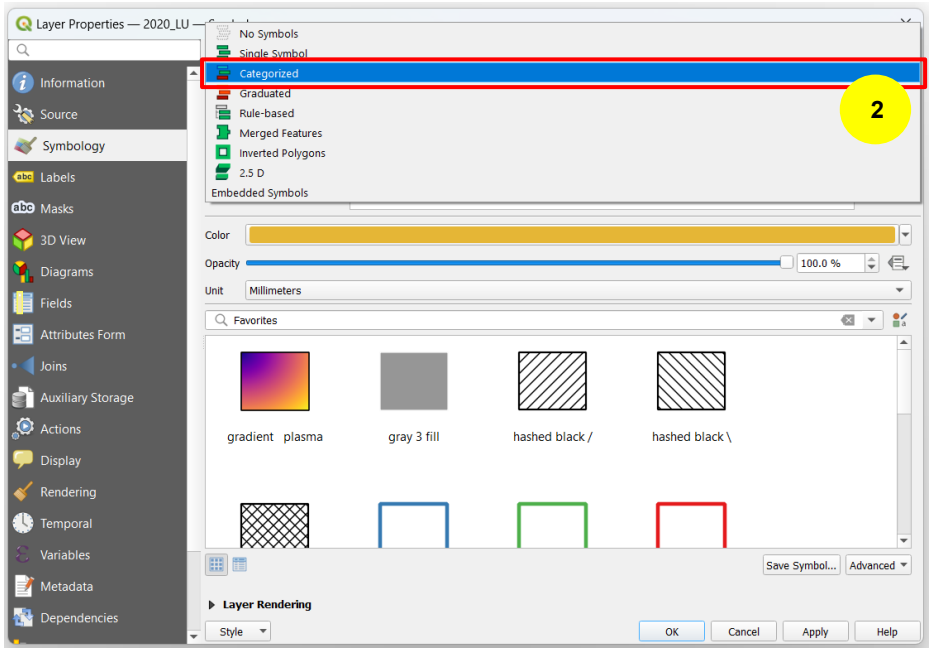


5.9 Outlines of the vector layer will be removed from this process as follows.

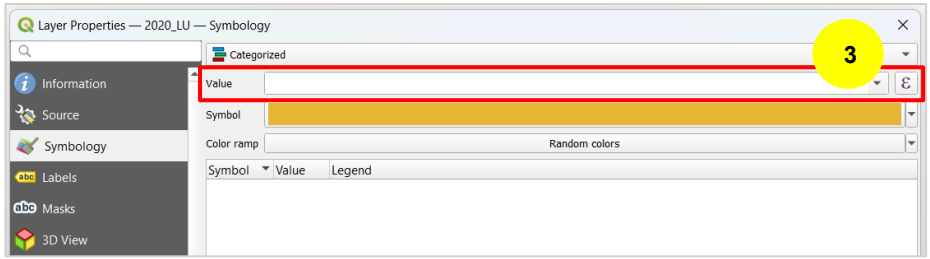


5.10 Let's categorize this vector layer. For that, again open the layer properties and go to the "**Symbology**" properties tab. Then, click on "**Single symbol**" and expand it. Select "**Categorized**" from the expanded list.

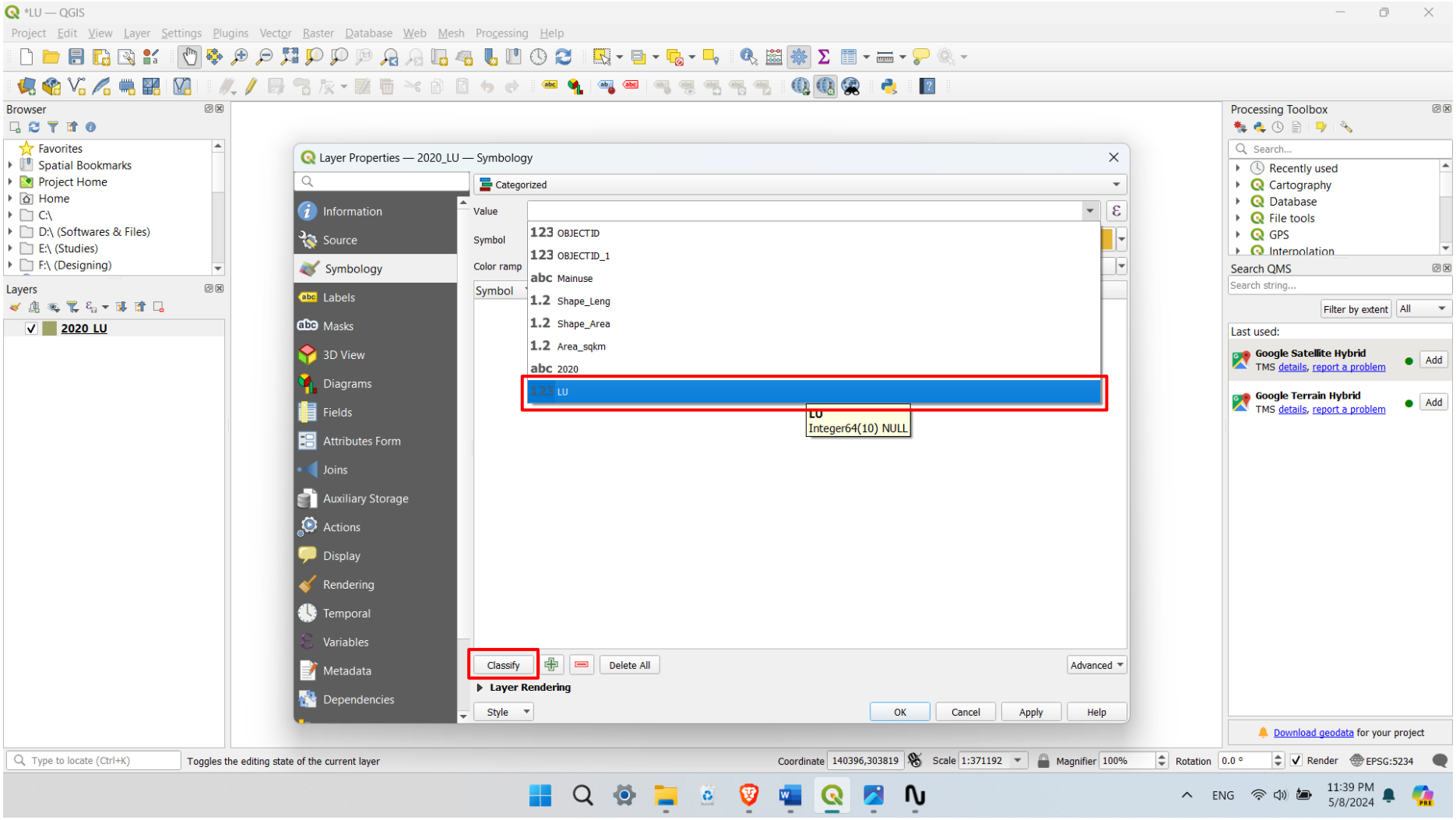




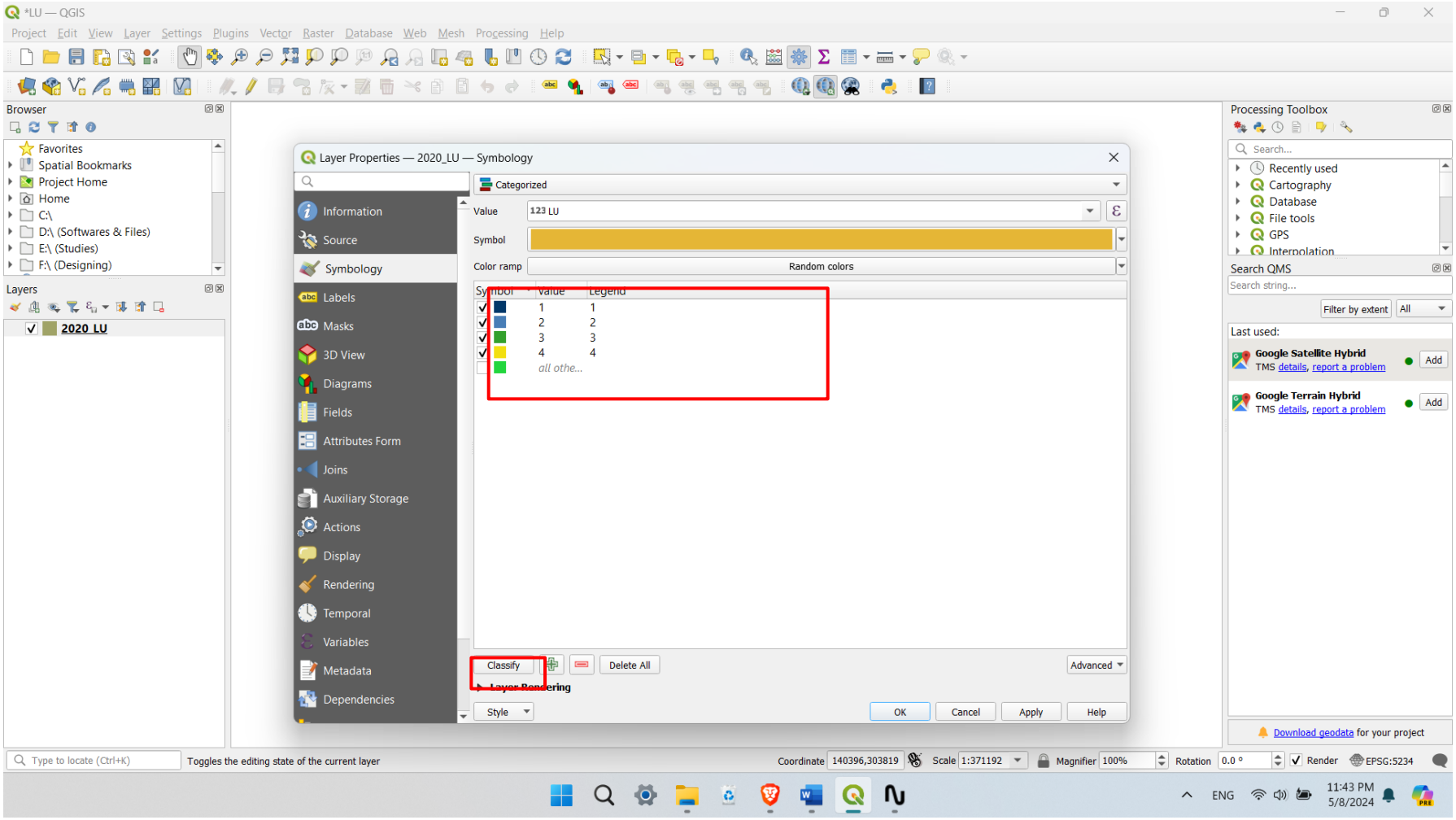
5.11 After selecting the "**Categorized**" option, the controls will be shown here like this. Next, expand the option "**Value**"



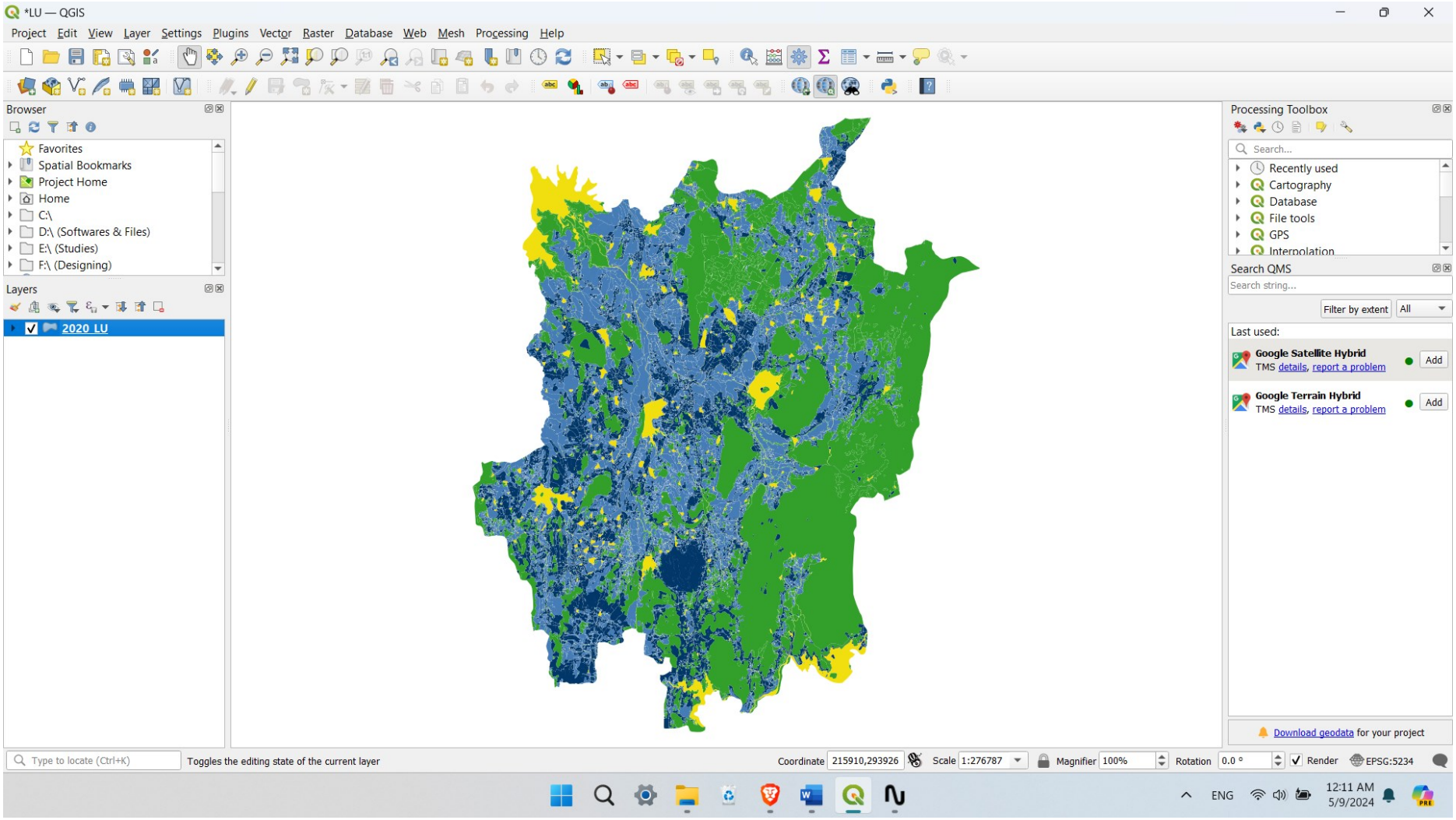
5.12 Select the field “**LU**” from this expanded list. After selecting the field, click on “**Classify**”.



5.13 The classification will be displayed as follows. If you want to change the colors of each category, double-click on the color from the classification and select the color that you want. Or you can change the **color ramp**. Then, click on “**Apply**” and “**OK**”.



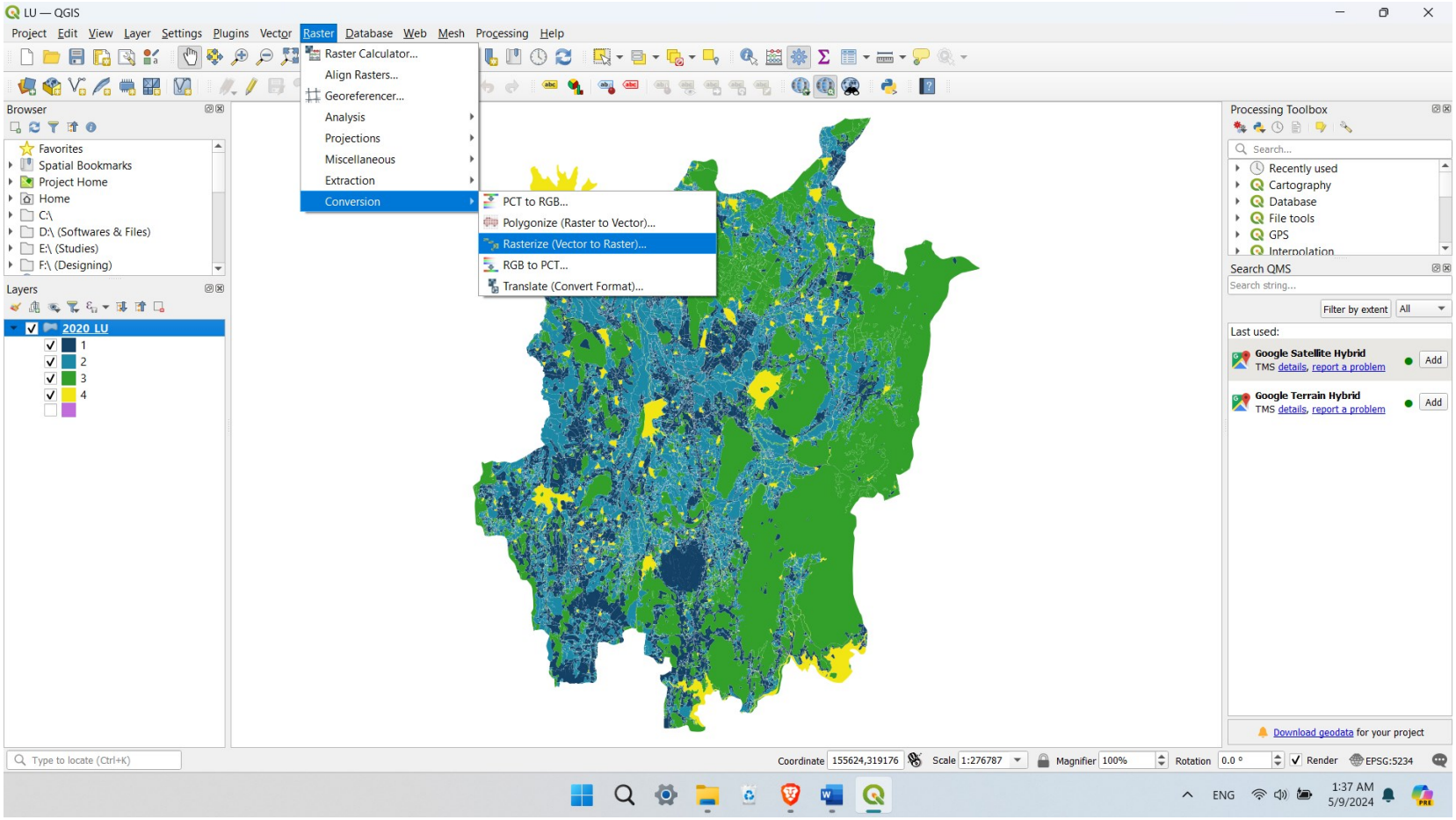
Here is the classification according to the main 4 land use categories, that we introduced to the Dambulla region.



Rasterization with QGIS 3.22.7

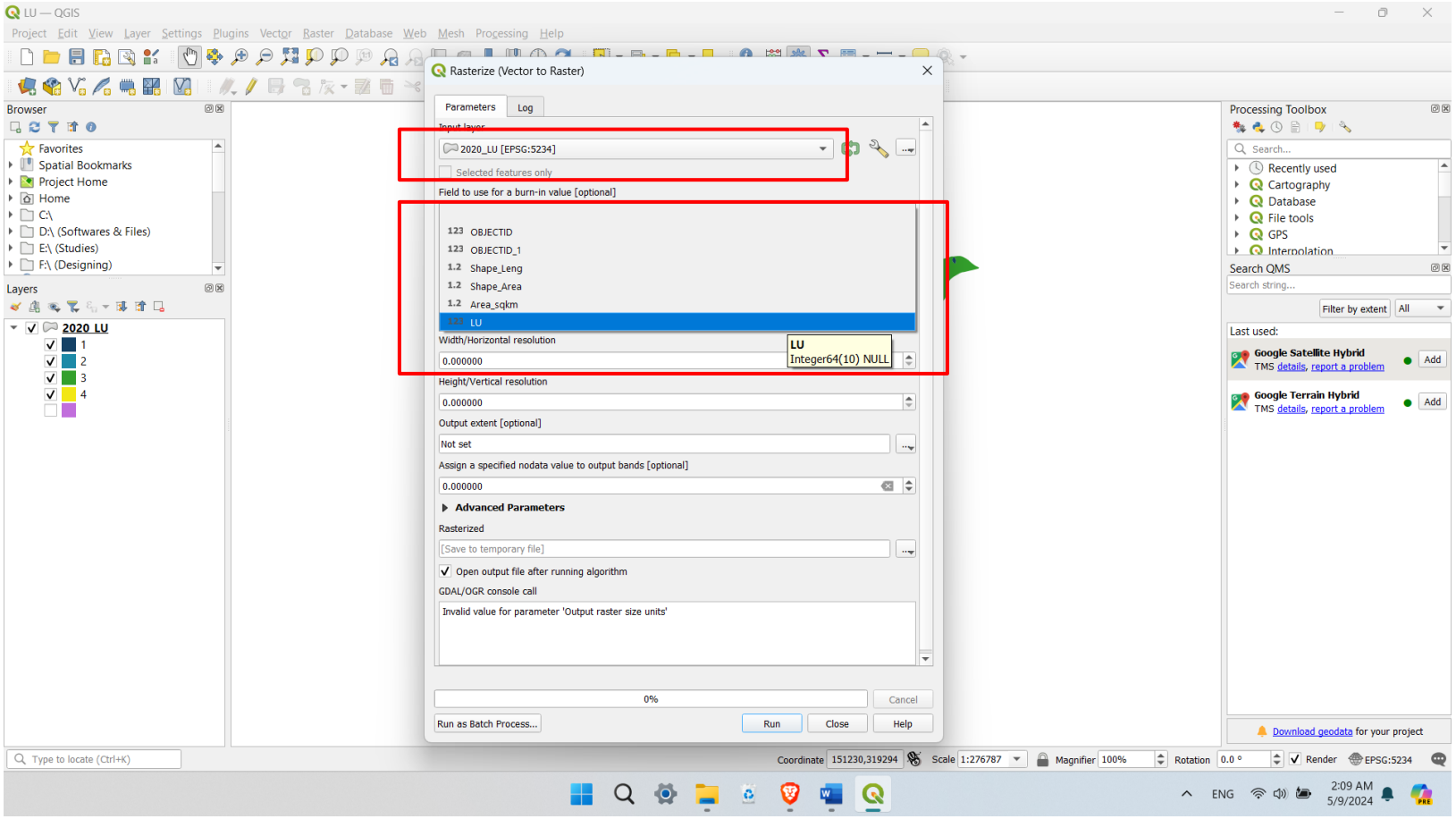
To convert this vector layer into a raster layer, open the "**Rasterize**" tool as follows.

Click on "Raster" in the toolbar > Conversion > Rasterize (Vector to Raster)

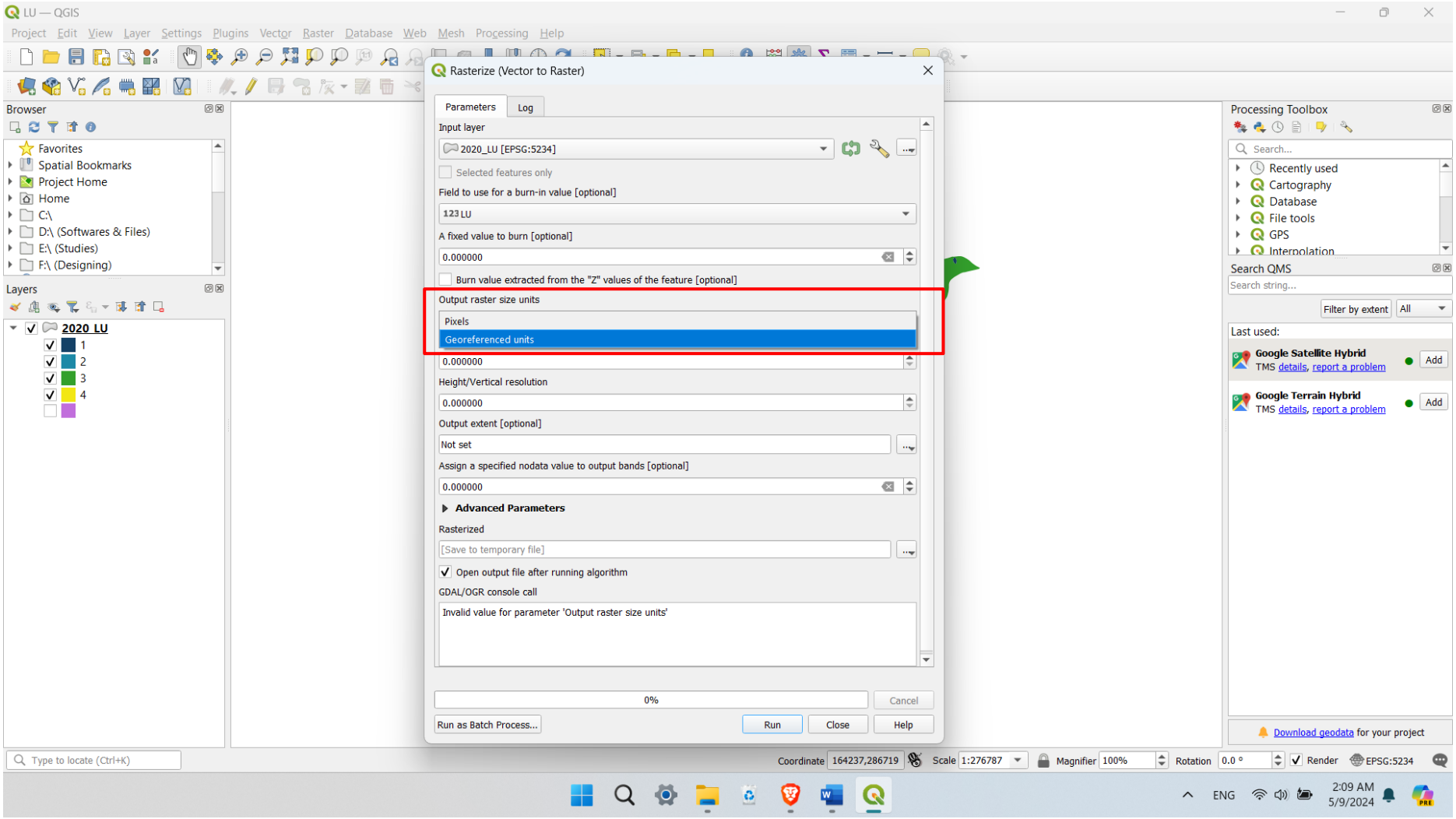


Then, the Rasterize tool will appear on the screen. Select the layer you want to convert to a raster on the “**Input layer**”.

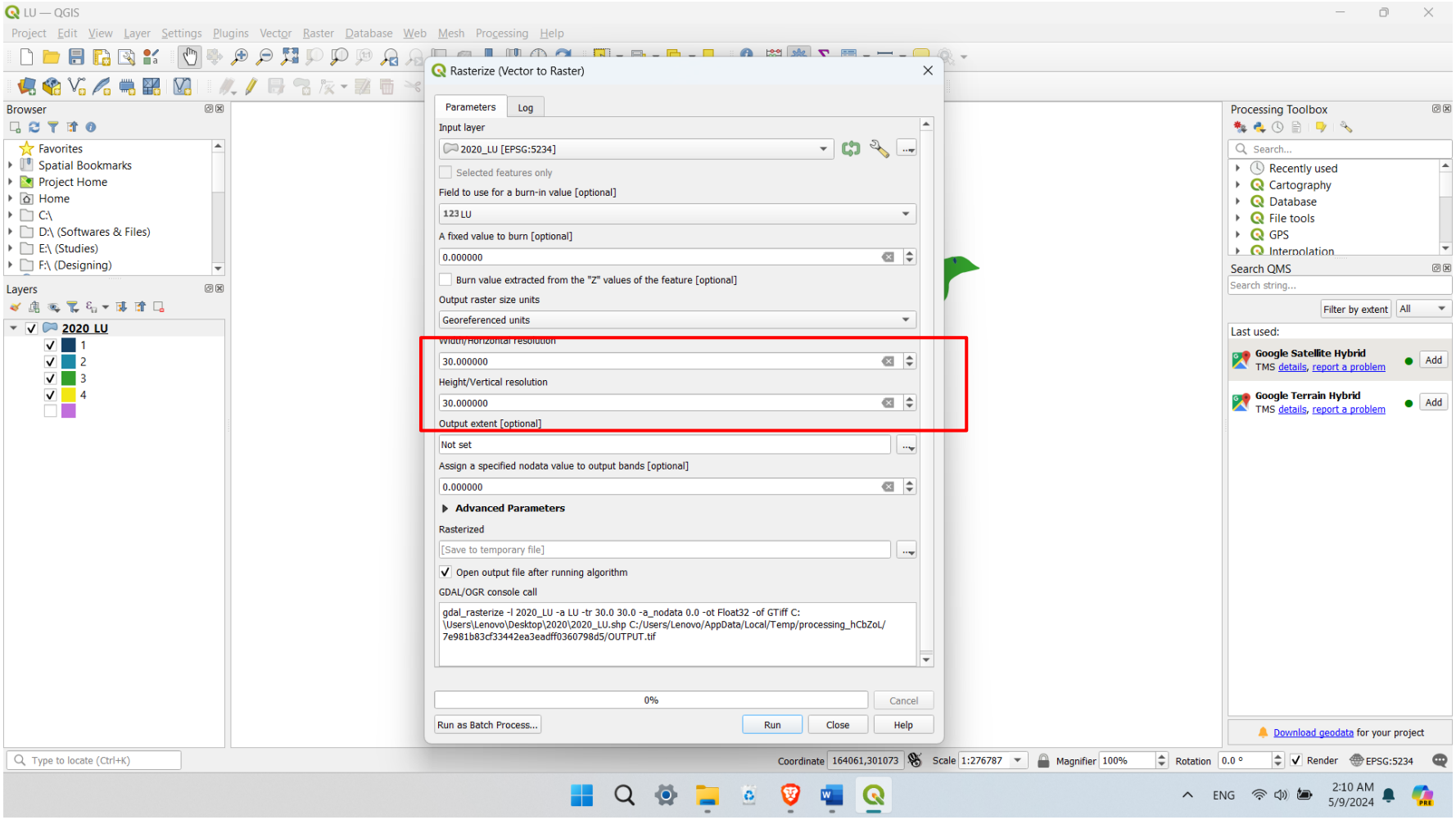
Next, expand the “**Field to use for a burn-in value**” option and select the numeric field as follows. Here, we are going to rasterize this layer through the field "**LU**".



Then, select the “**Output raster size units**” as “**Georeferenced units**”.

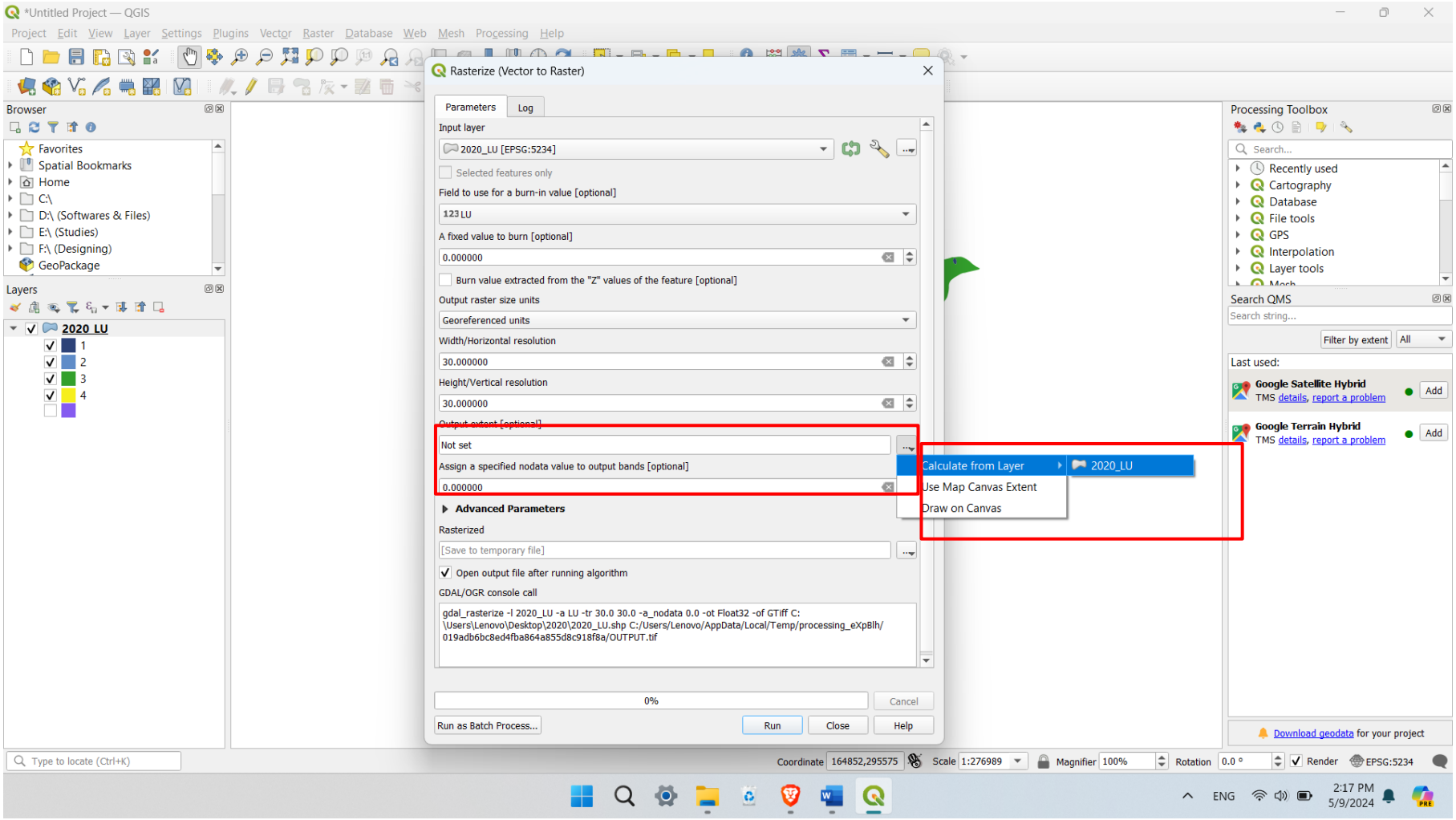


Next, enter the “**Width/Horizontal**” and “**Height/Vertical**” resolutions as “**30**”. Generally, we use the pixel size of a raster layer as 30x30. That's why we entered the same size here. But depending on the dataset we are using; we can resample the layer and change the pixel size.

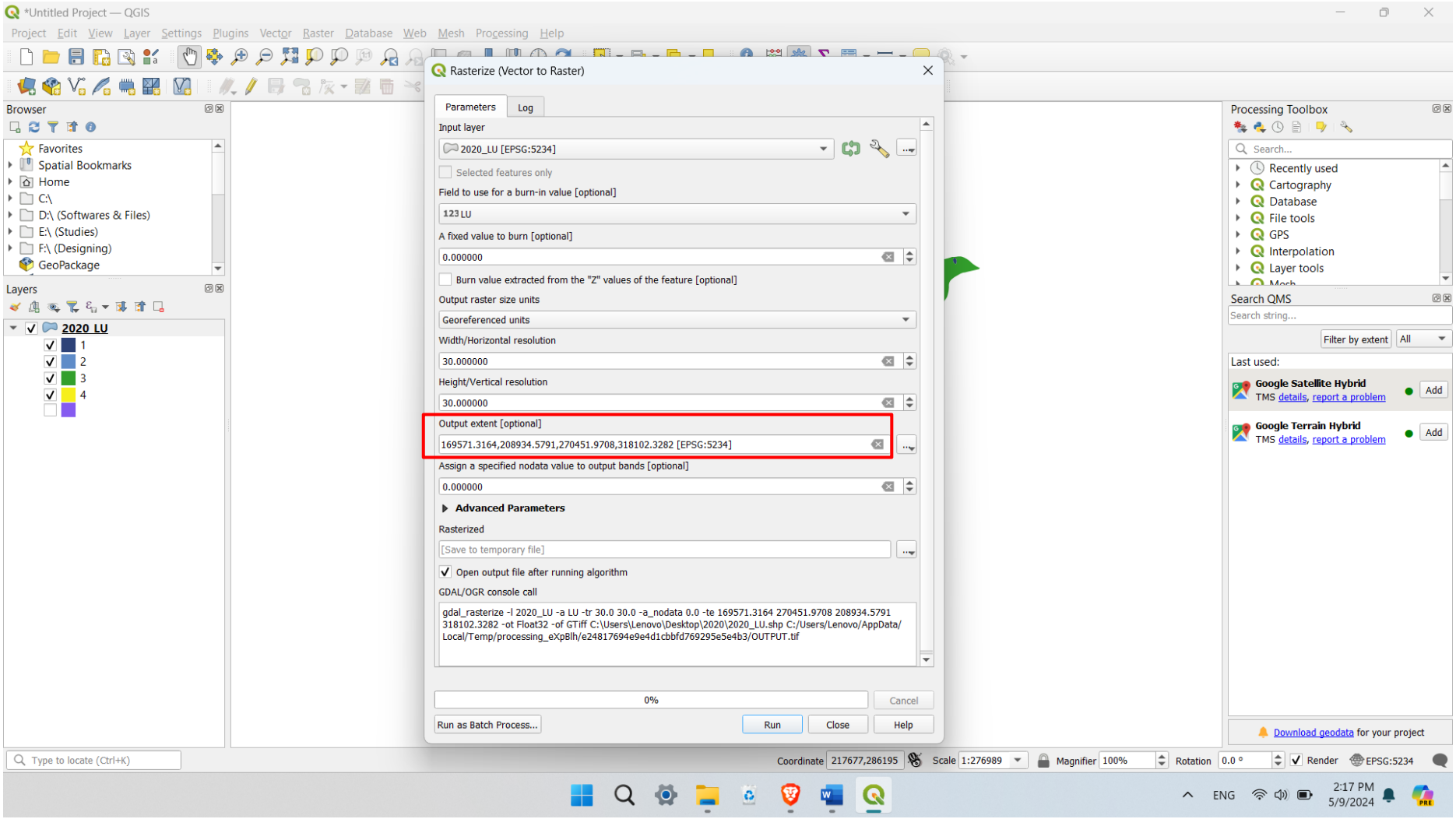


Next, we select the output extent. After clicking the icon shown in the corner of that option, we can select the desired layer as below and use the output extent.

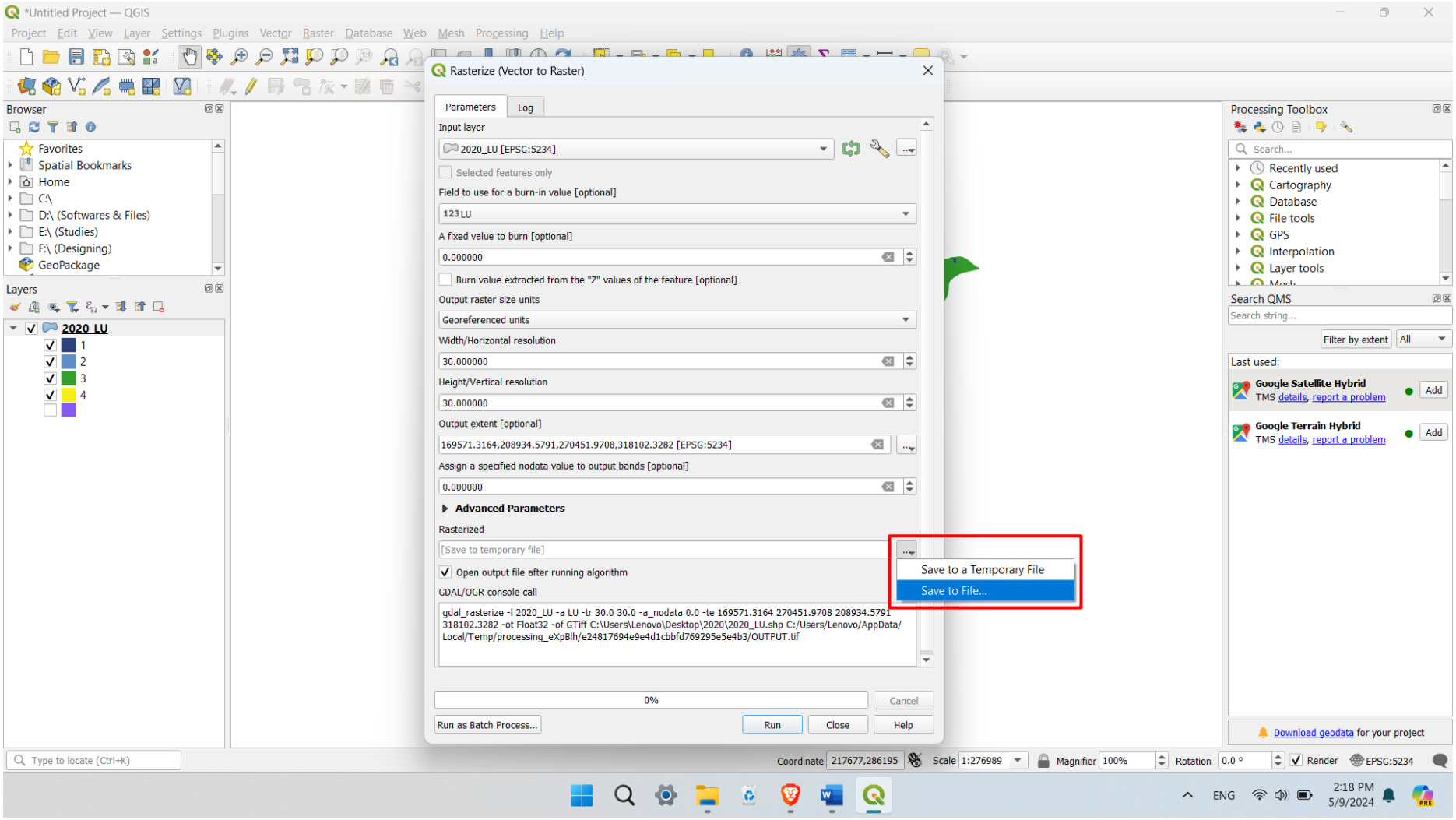
Click on the icon > Calculate from layer > Select the layer



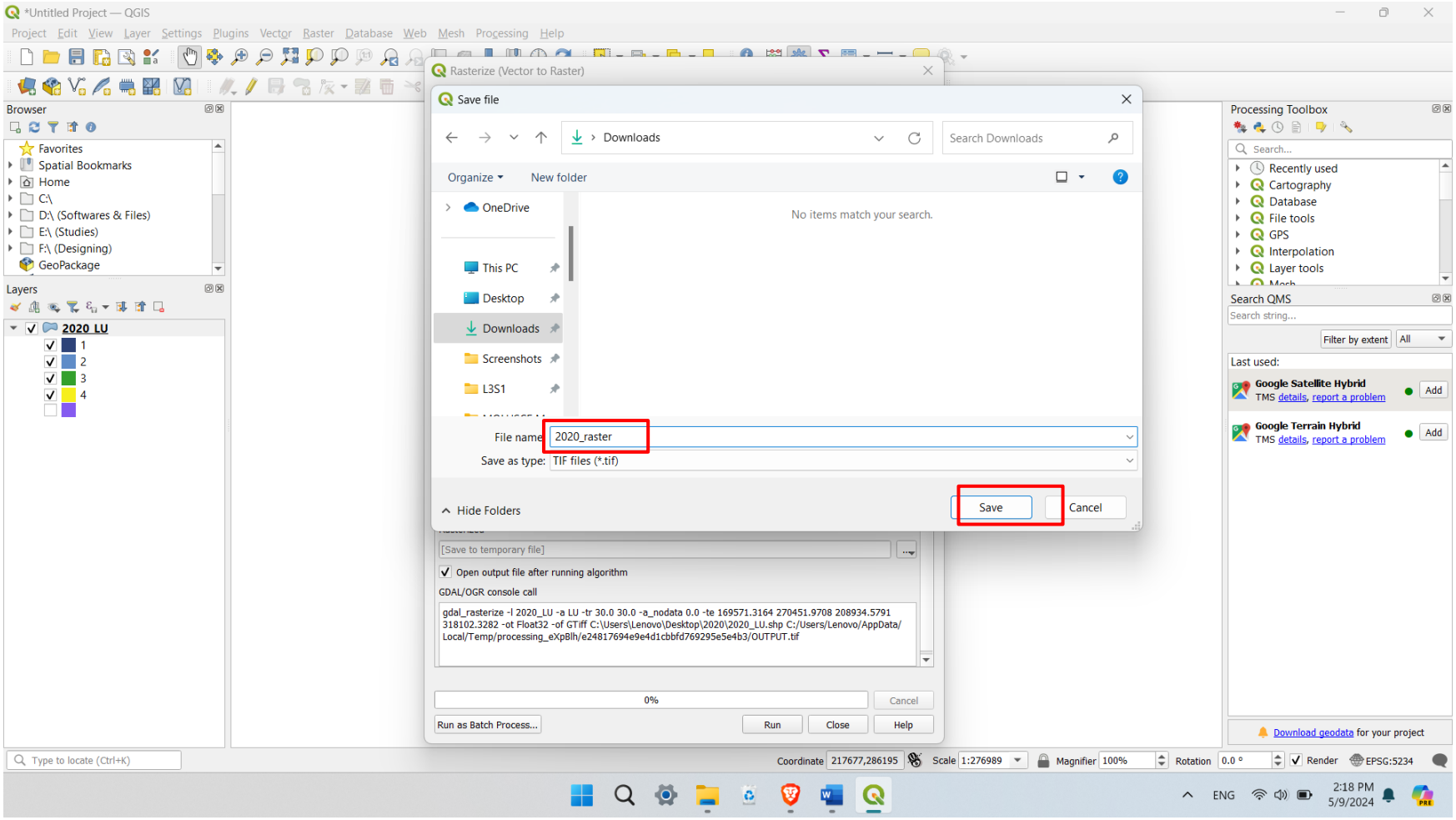
The output extent will be set up according to the above-selected layer as follows.



Then, browse a location to save this layer. For that, click on the below icon and select “**Save to File**”.

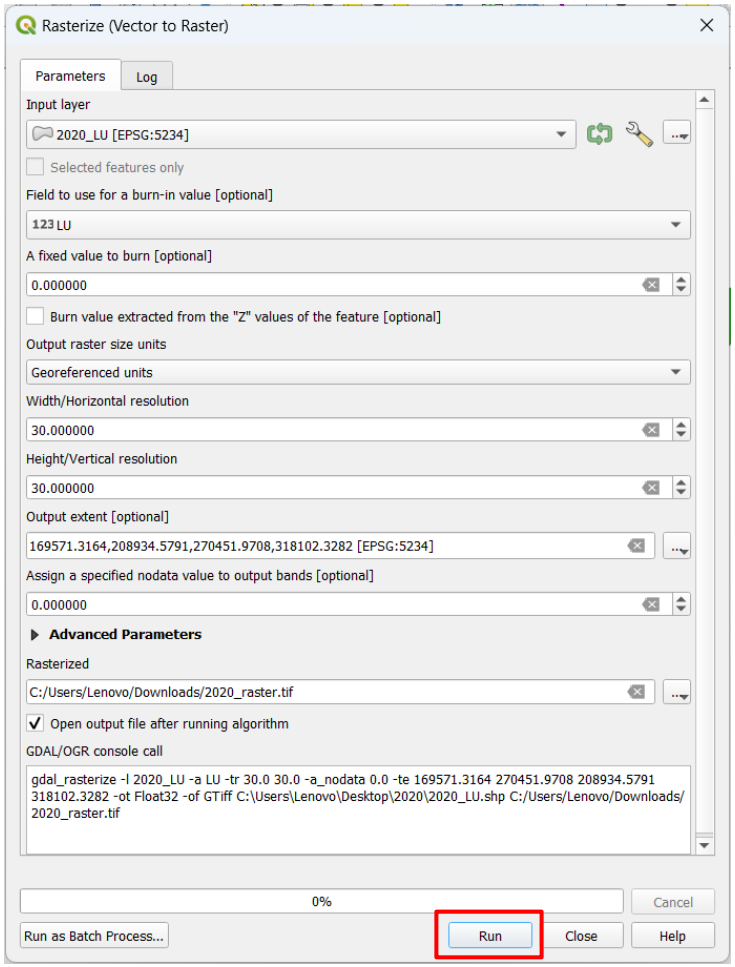


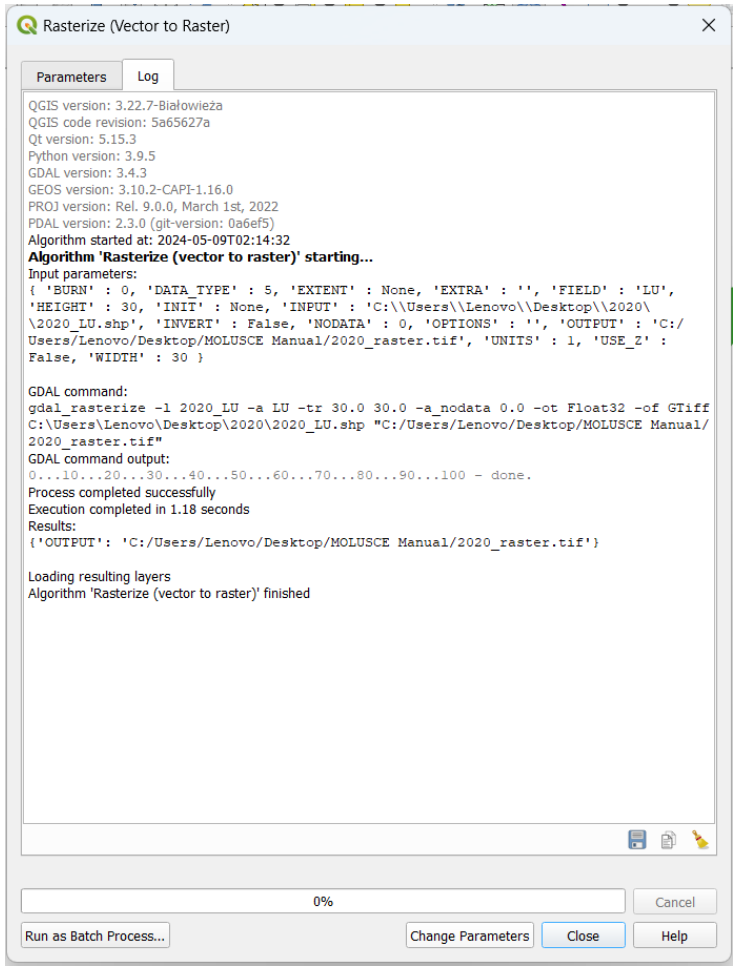
As follows, now you can browse and select a location on your computer to save the layer. Once you select the location and set the **File name** as below, click on "**Save**" to proceed.



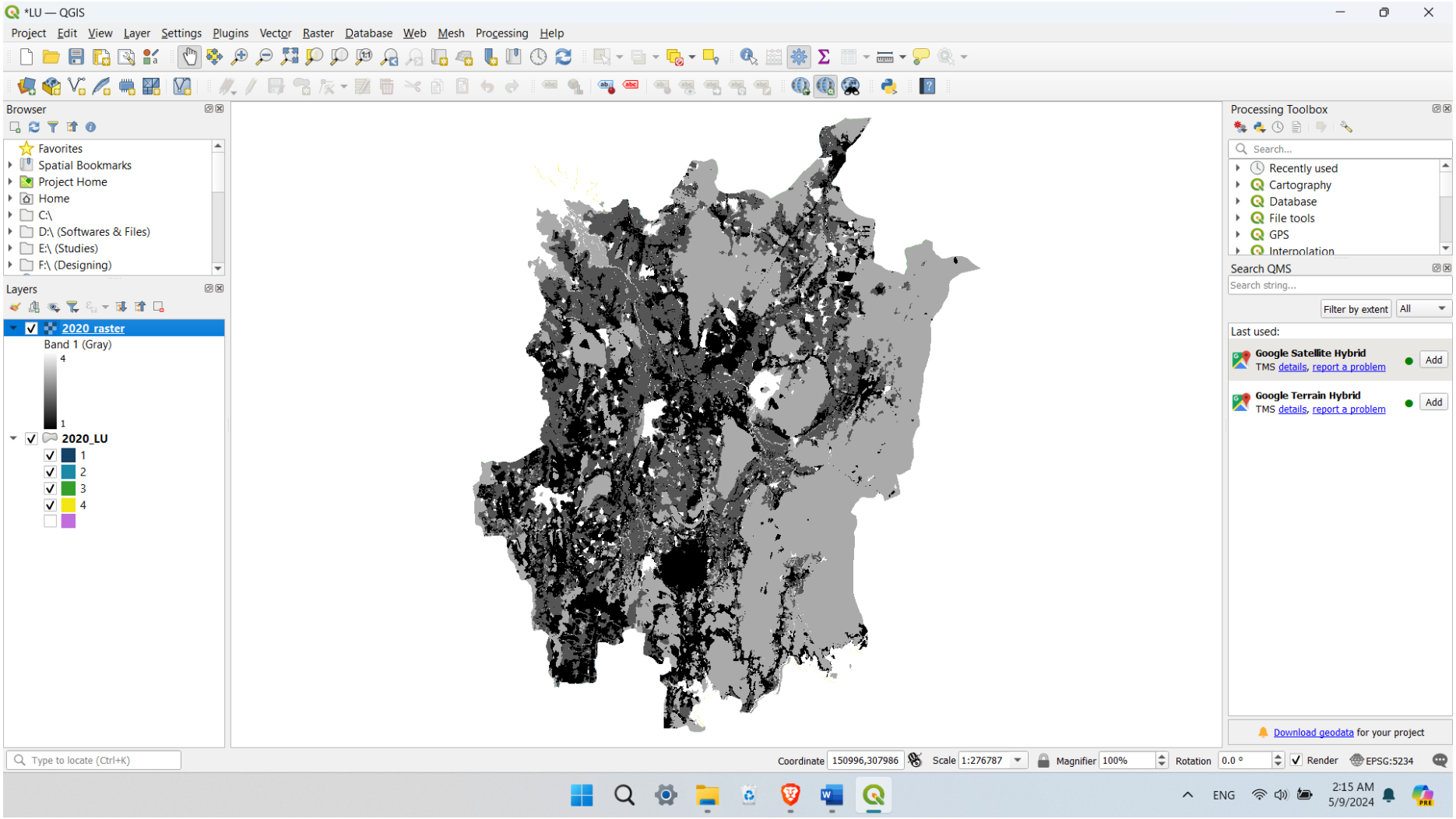
Now all the parameters are ready. Click on "**Run**".

After this is finished running, a message will appear on the screen as shown in the image below right side.



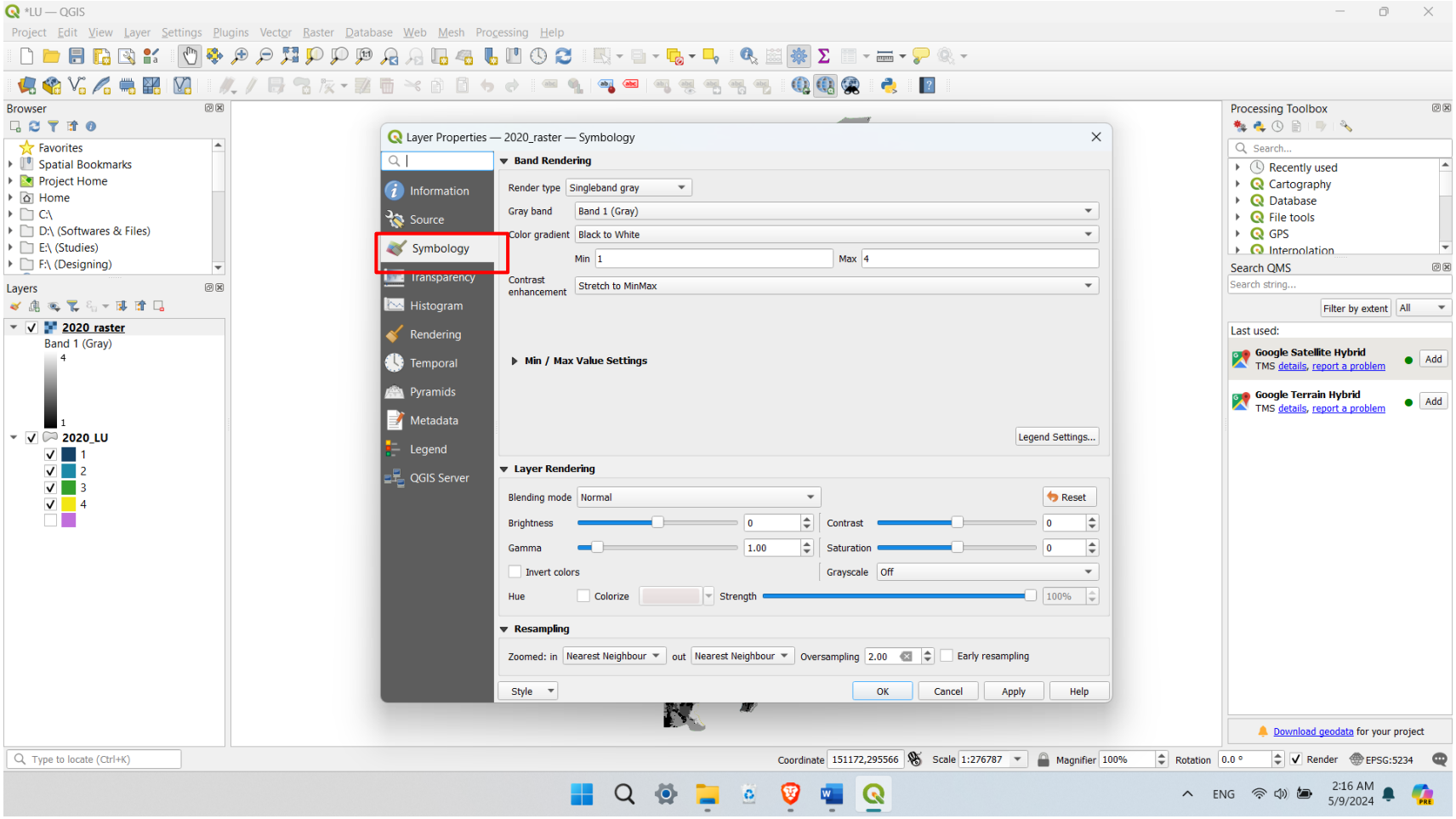


Now the raster layer can be seen as follows.

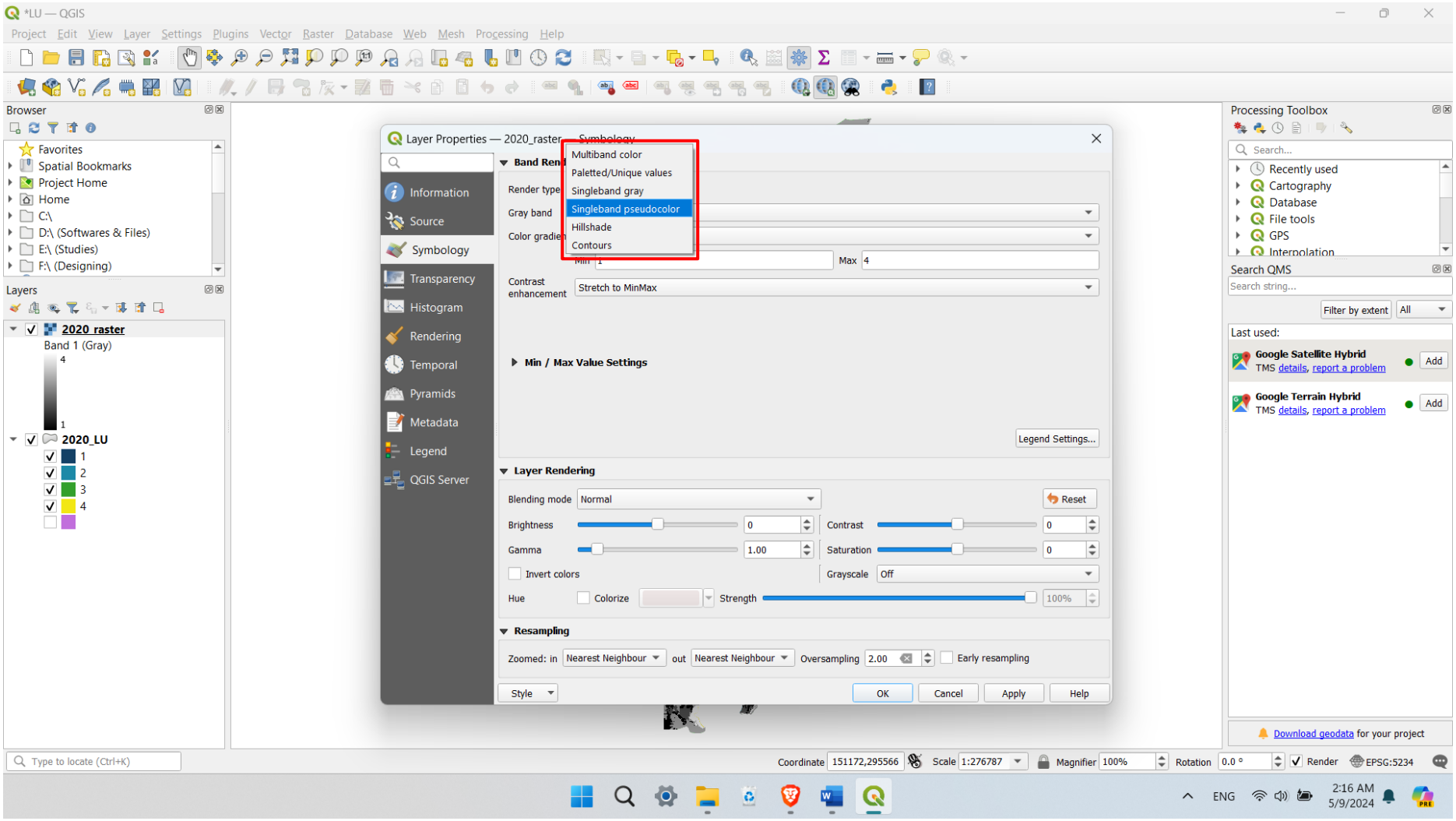


Once the rasterization is finished as above, follow the steps below for ease of identifying their land use categories separately in clear colors.

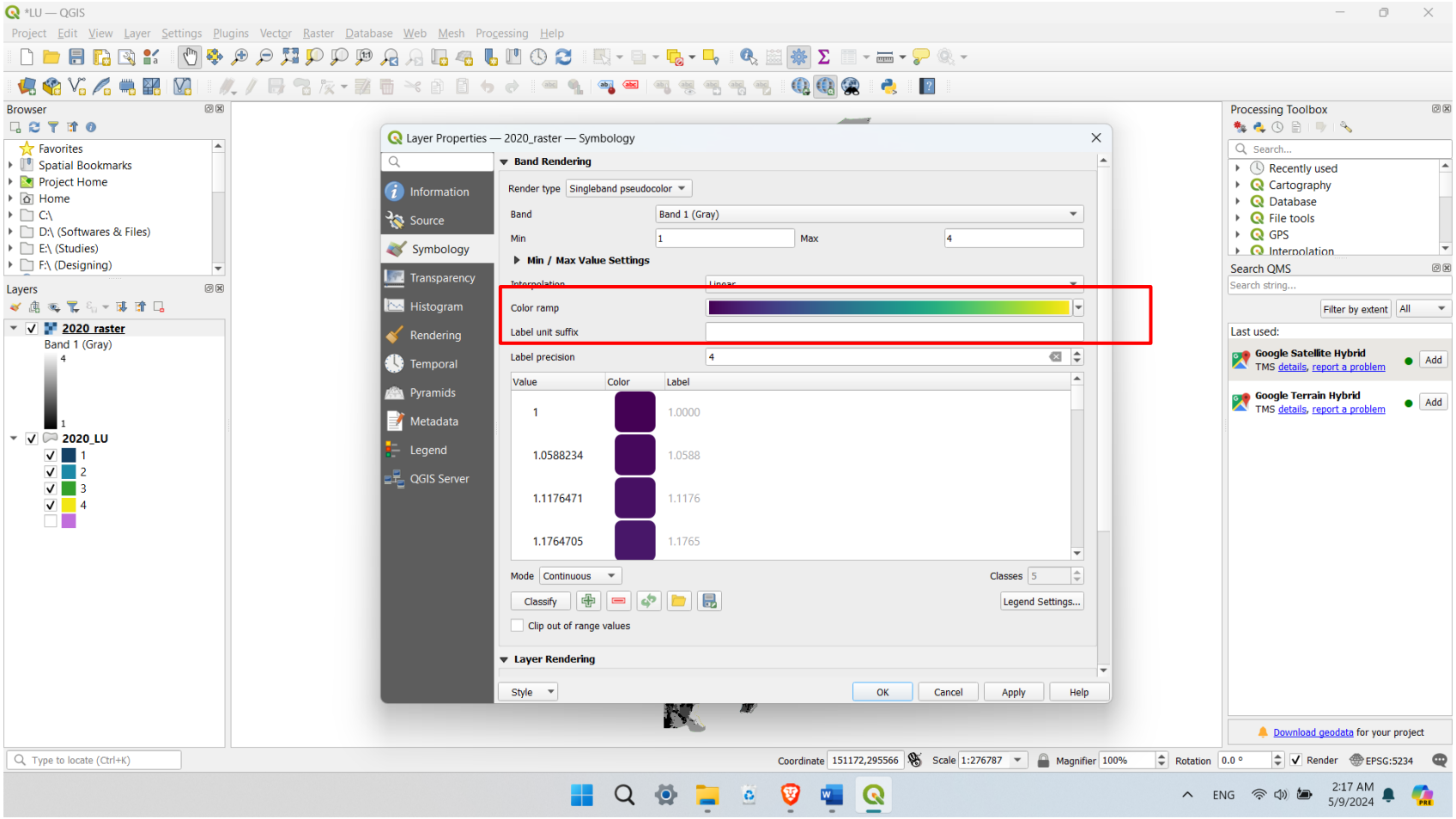
- Right-click on the layer to open the layer properties and go to the “**Symbology**” tab.



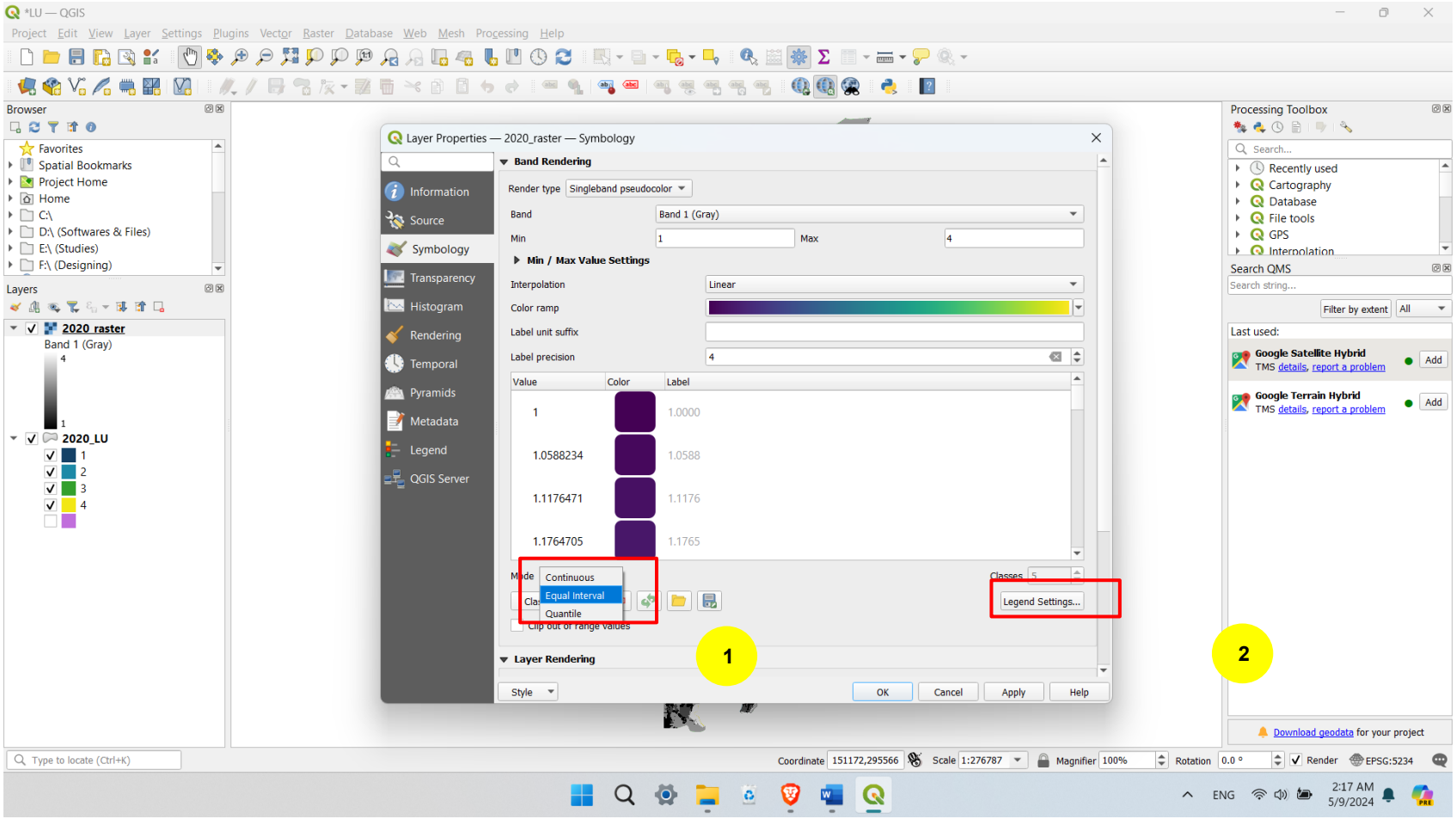
- Set the “**Render type**” as “**Singleband pseudocolor**”.



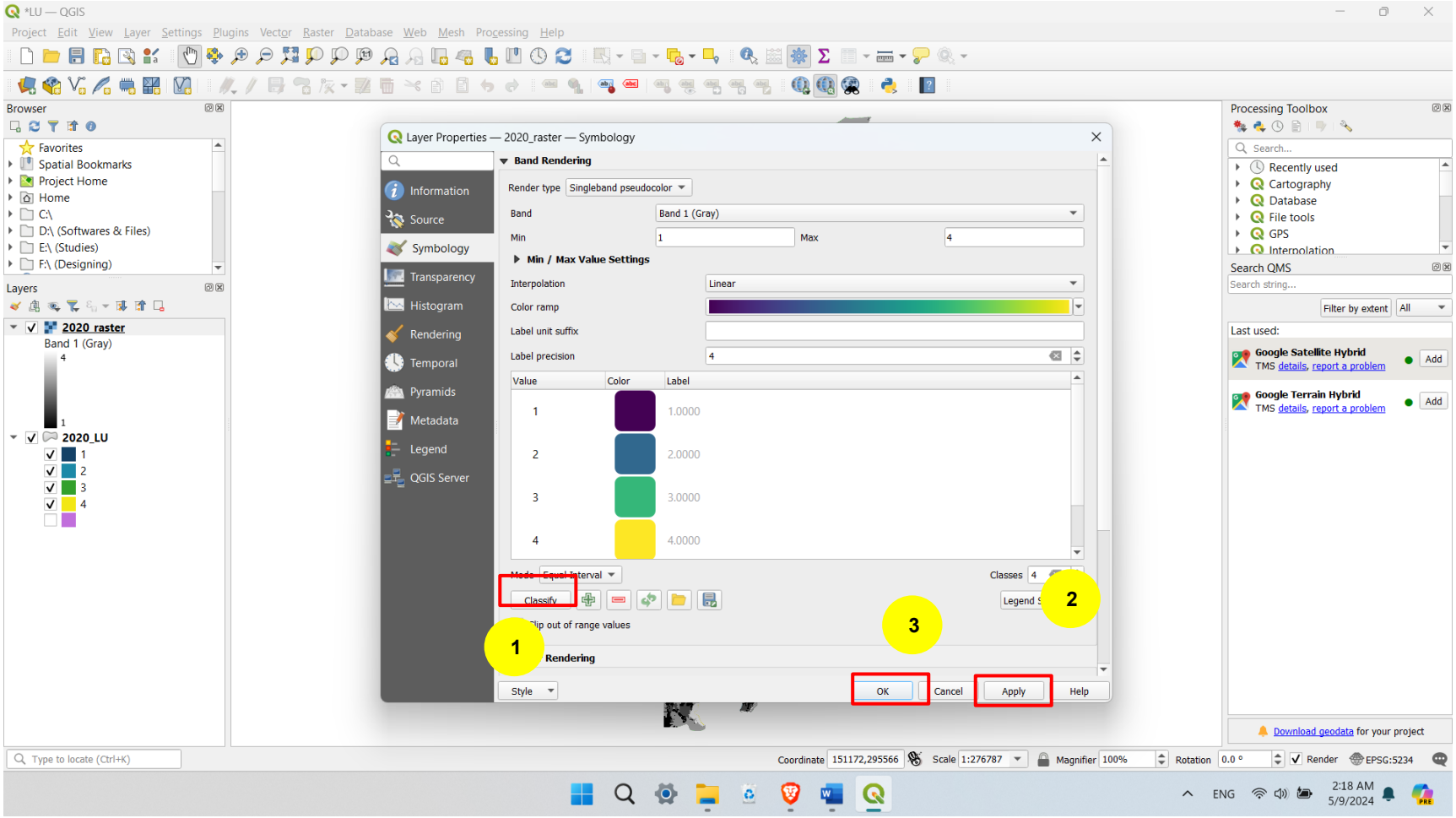
- Set the “**Interpolation**” as “**Linear**”.
- Then you can select any color combination under “**Color ramp**”.



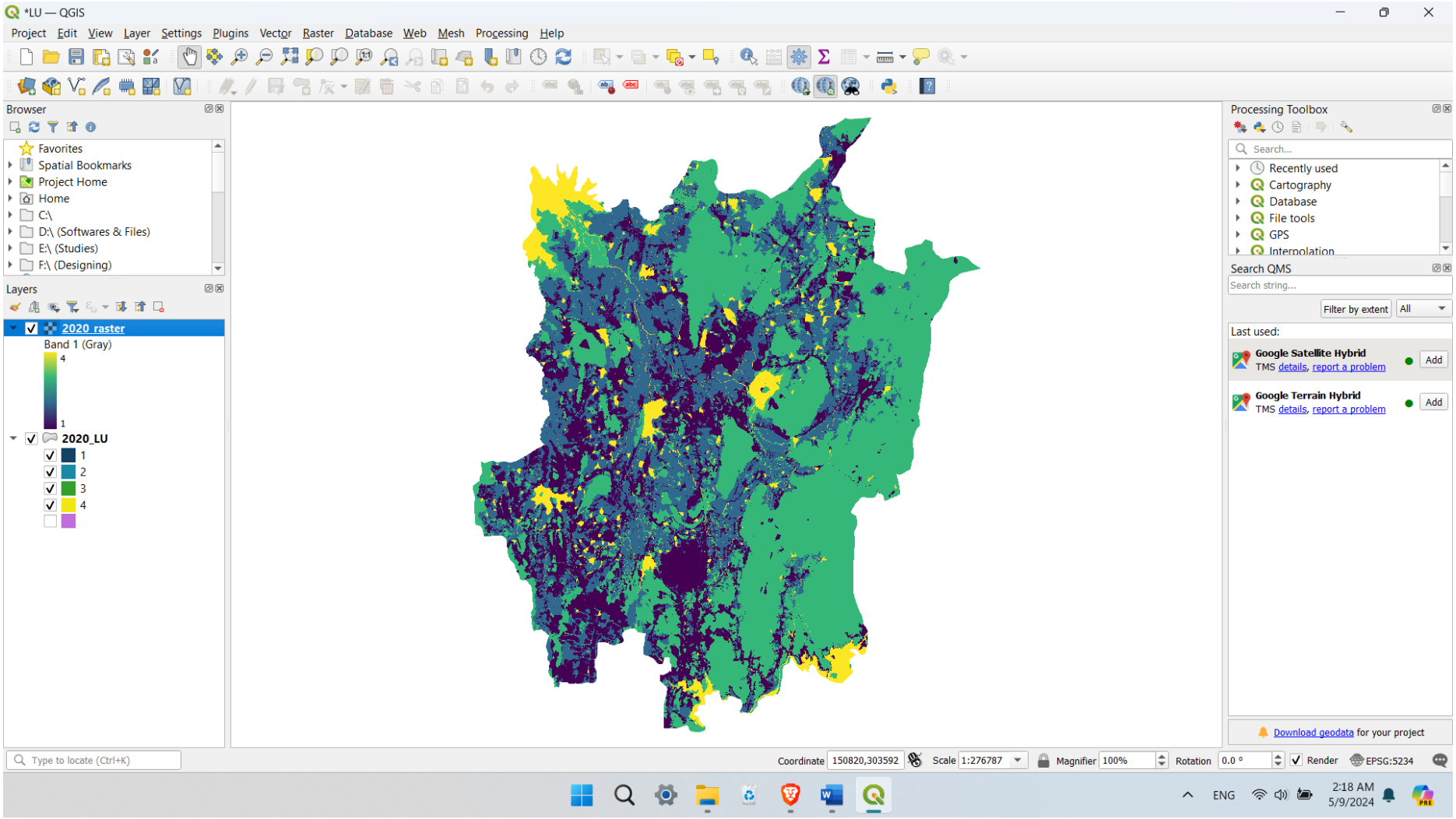
- Set the "**Mode**" as “**Equal Interval**” and set the "**Classes**" as “**4**”. (The number of classes may vary on your land use layer’s classification. In this layer, there are 4 land use categories. That’s why the number of classes is set as “4”)


*LU — QGIS
Project Edit View Layer Settings Plugins Vector Raster Database Web Mesh Processing Help
Browser
Favorites
Spatial Bookmarks
Project Home
Home
C:\
D:\ (Softwares & Files)
E:\ (Studies)
F:\ (Designing)
Layers
2020_raster
Band 1 (Gray)
2020_LU
1
2
3
4
Layer Properties — 2020_raster — Symbology
Information
Source
Symbology
Transparency
Histogram
Rendering
Temporal
Pyramids
Metadata
Legend
QGIS Server
Band Rendering
Render type
Singleband pseudocolor
Band
Band 1 (Gray)
Min
1
Max
4
Min / Max Value Settings
Interpolation
Linear
Color ramp
Label unit suffix
Label precision
4
Value
Color
Label
1
1.0000
1.0588234
1.0588
1.1176471
1.1176
1.1764705
1.1765
Mode
Continuous
Equal Interval
Quantile
Classes
Legend Settings...
Clip out of range values
Layer Rendering
Style
OK
Cancel
Apply
Help
1
2
Processing Toolbox
Search...
Recently used
Cartography
Database
File tools
GPS
Interpolation
Search QMS
Search string...
Filter by extent
All
Last used:
Google Satellite Hybrid
TMS details, report a problem
Add
Google Terrain Hybrid
TMS details, report a problem
Add
Download geodata for your project
Type to locate (Ctrl+K)
Coordinate 151172,295566
Scale 1:276787
Magnifier 100%
Rotation 0.0 °
Render
EPSG:5234
ENG
2:17 AM
5/9/2024

- After setting the number of classes, click on “**Classify**”.
- Finally, click on “**Apply**” and “**OK**”.



The land use layer will appear on the workspace as follows.



When utilizing the MOLUSCE plugin in QGIS, it's essential to ensure that all input layers have the same number of rows and columns, which ensures matching geometries. This requirement is critical for several reasons,

- **Matching geometries**

  For successful processing in MOLUSCE, the geometries of input rasters must align. This alignment entails having consistent characteristics such as cell size, coordinate reference system (CRS), and spatial extent.

- **Why matching geometry matters**

  During the rasterization process, where vector data (e.g., roads or land use polygons) is converted to raster format, values are assigned to raster cells based on the vector data. Matching geometries ensure that this assignment occurs accurately, with vector data aligning correctly with the raster grid. Consistent geometries also contribute to reliable analysis, as MOLUSCE relies on uniform input data for accurate land use change simulations.

- **Steps to ensure matching geometries**

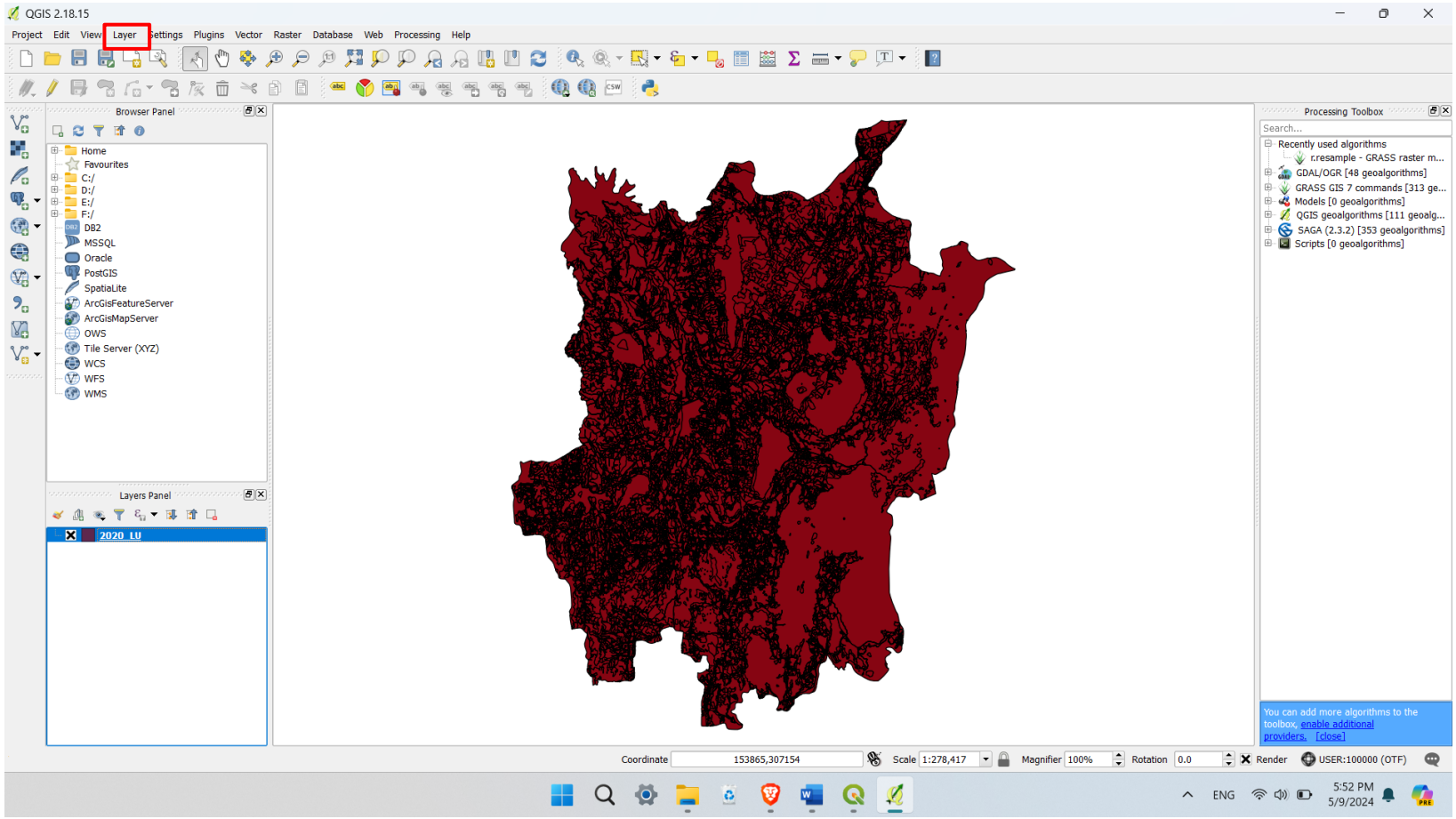
  To achieve matching geometries, consider resampling input rasters to a common cell size if variations exist. Additionally, ensure all layers share the same CRS and adjust the extent of the rasters to align properly. By following these steps, we can maintain consistent geometries, leading to accurate and reliable results when utilizing the MOLUSCE plugin for land use change simulations in QGIS.

The rows and columns count of the layers we use here should be 1725 and 1430 respectively, and the cell size should be 0.00025. These values were determined based on the pre-processed dataset we obtained while performing this analysis. Similarly, if you are engaged in this type of project, you need to resample the layers prepared above to adjust the cell size and other parameters as desired. **However, since those steps were not successful through the QGIS version 3.22.7 that we used until now, we hope to use QGIS version 2.18.15 to resample the layers.**

Starting with the step of converting the vector layer to a raster layer, the following is repeated through QGIS version 2.18.15. It shows how to equalize Rows and Columns count and resize cells. And all these can be done very smoothly by using the ArcMap software. Let's examine those steps next.

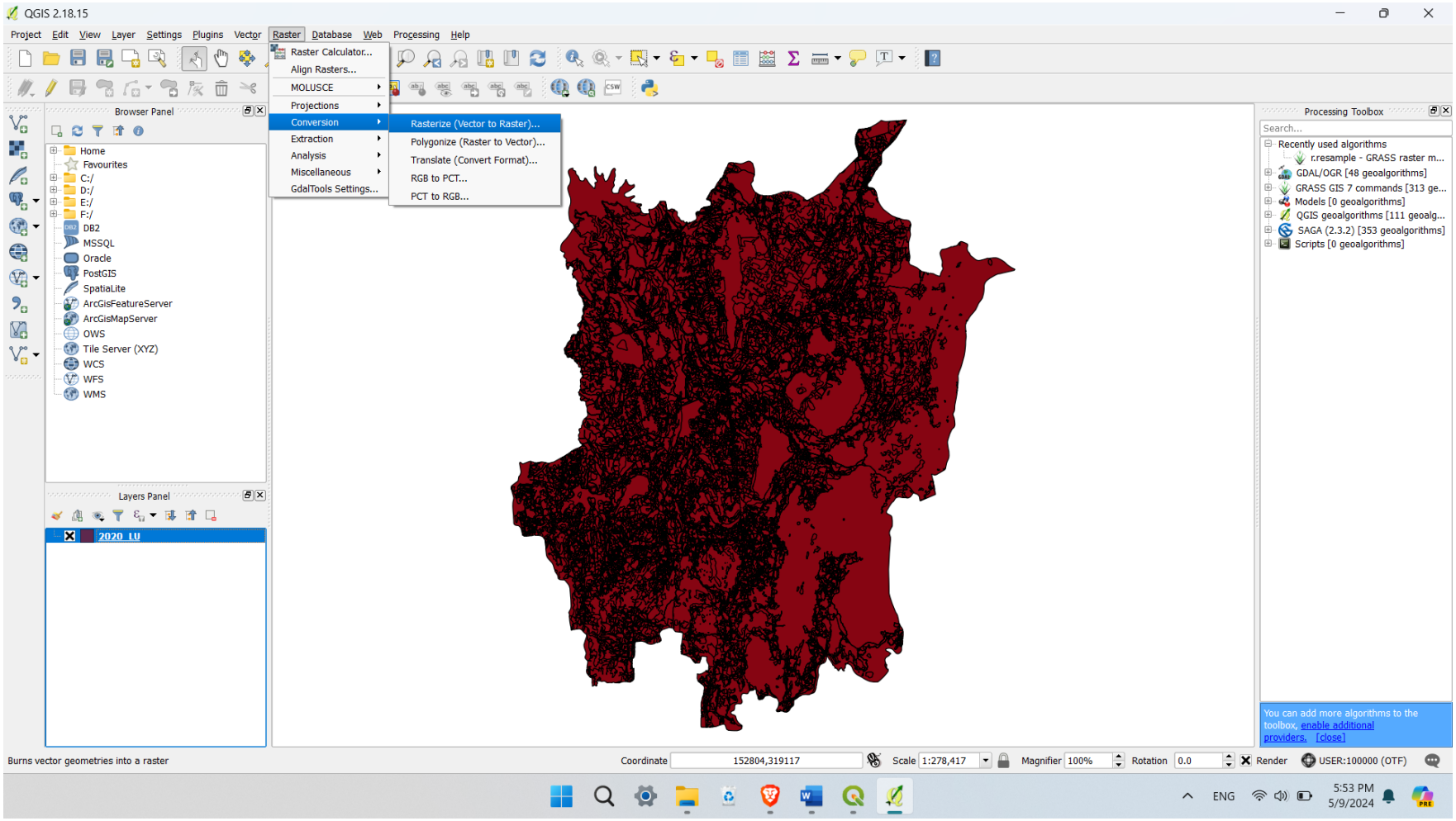
Rasterization with QGIS 2.18.15

- Open the updated land use layer with QGIS 2.18.15 as follows.
- For that, you can click on the “**Layer**” on the main toolbar and open the layer toolbar. Then, **Add Layer > Add Vector Layer**

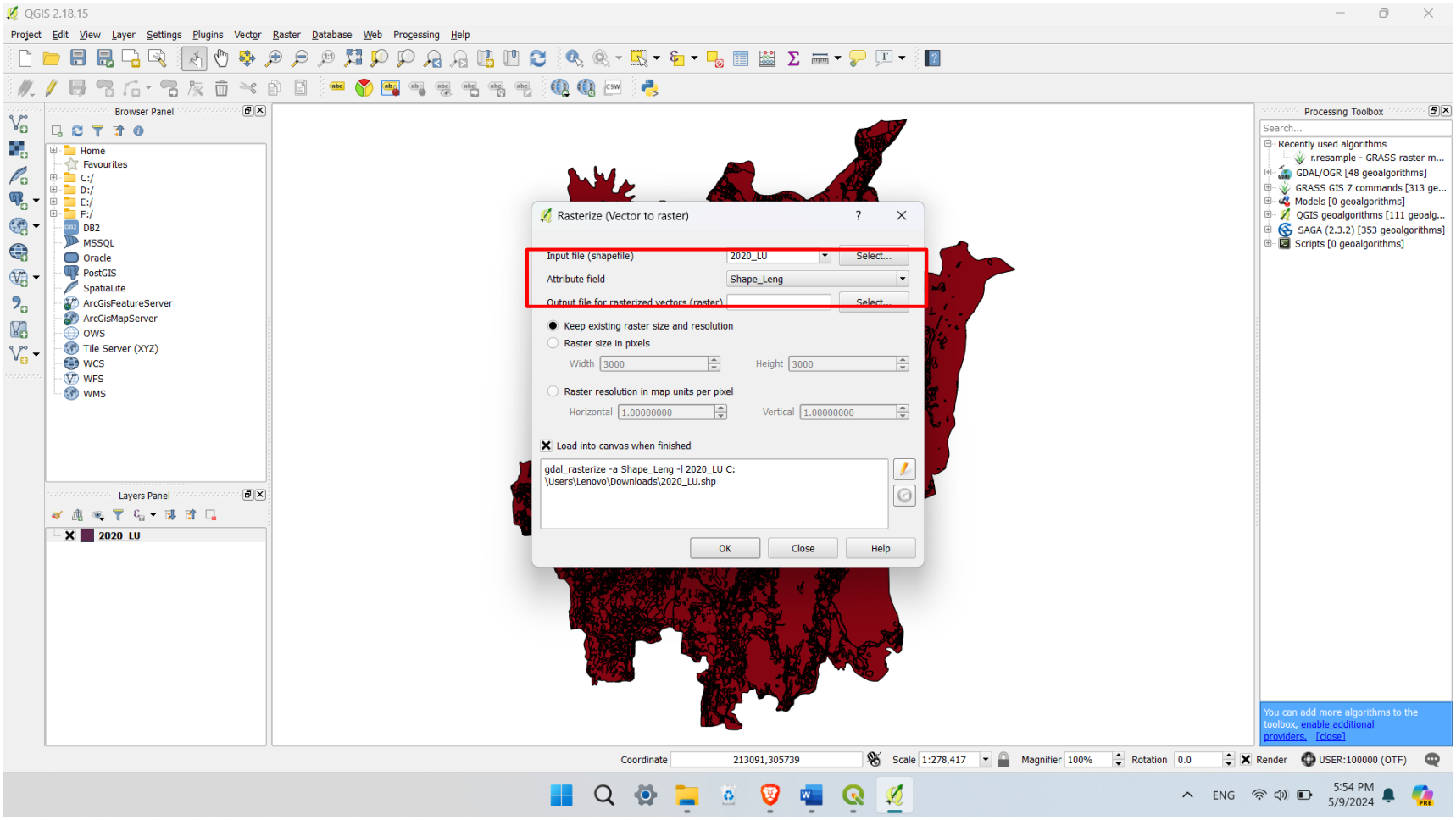


- Now let's convert this vector layer to a raster layer. For that, open the **Rasterize tool**.

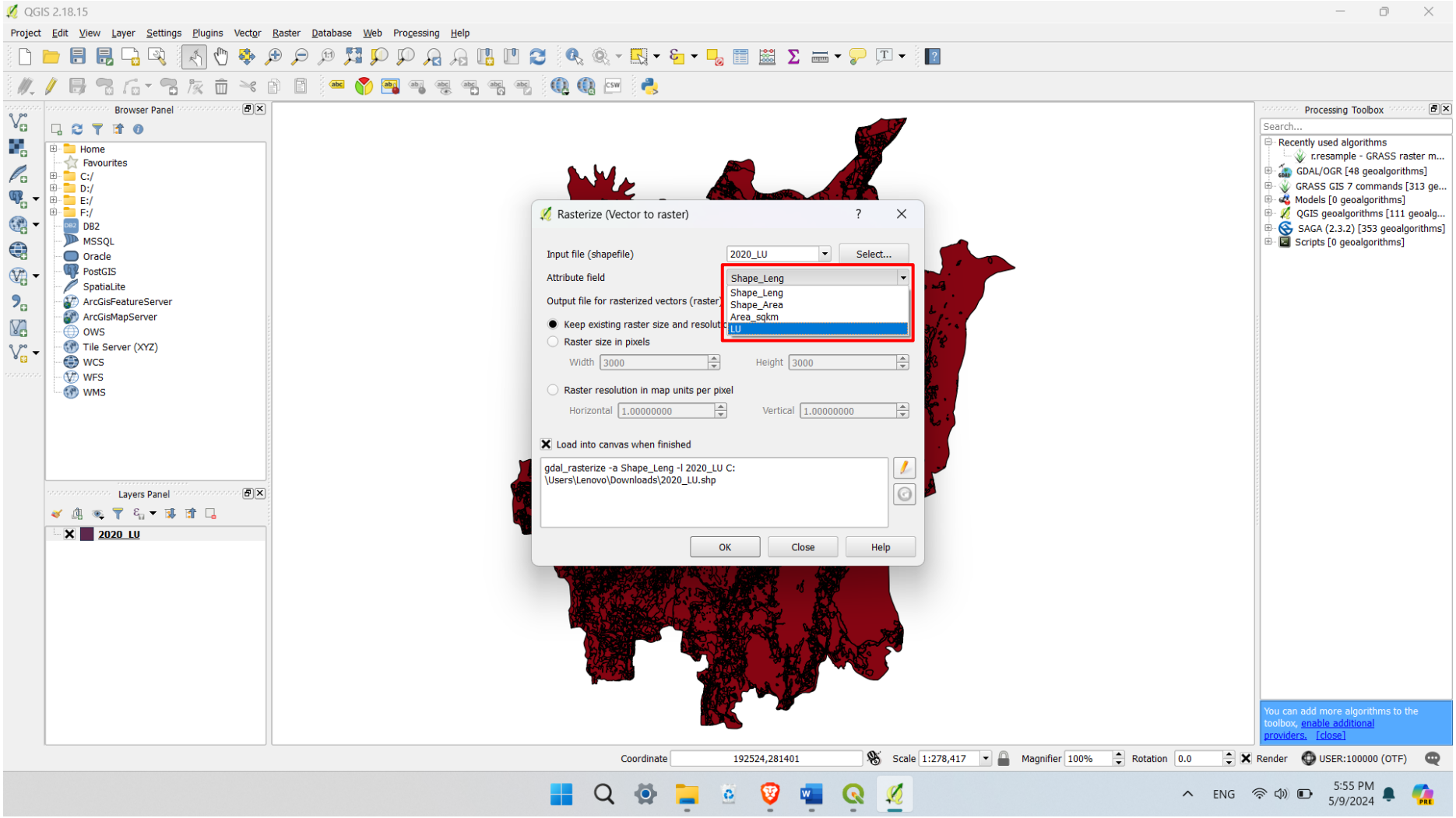
Click on the "**Raster**" on the main toolbar > **Conversion** > **Rasterize (Vector to Raster)**



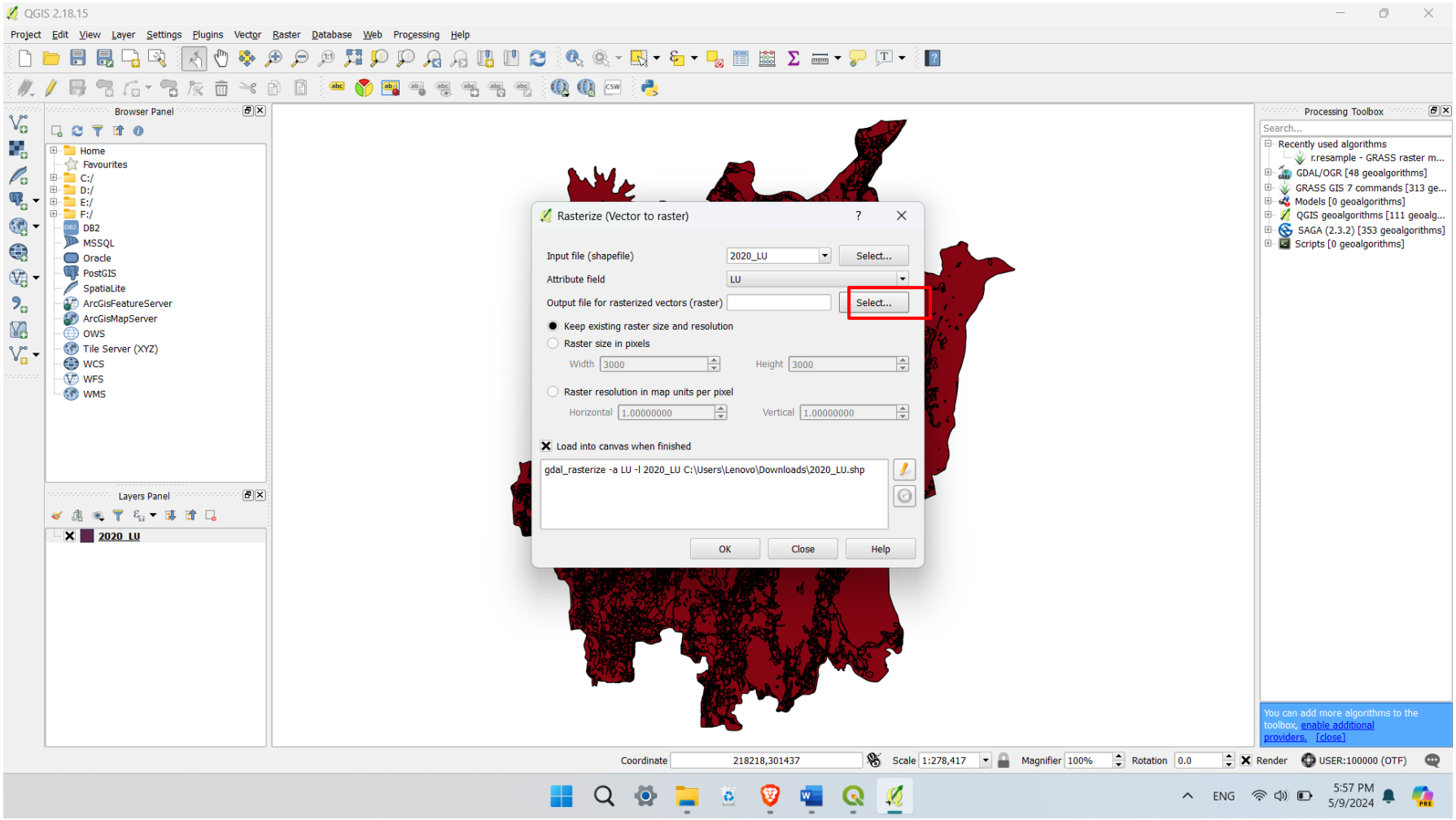
- Then the following window will open. First, select the vector layer as the **Input file (shapefile)** here.
- Next, we have to select the **Attribute field**. As you may remember, this rasterization process is done based on the field we select here. And, this field should be **numeric**.



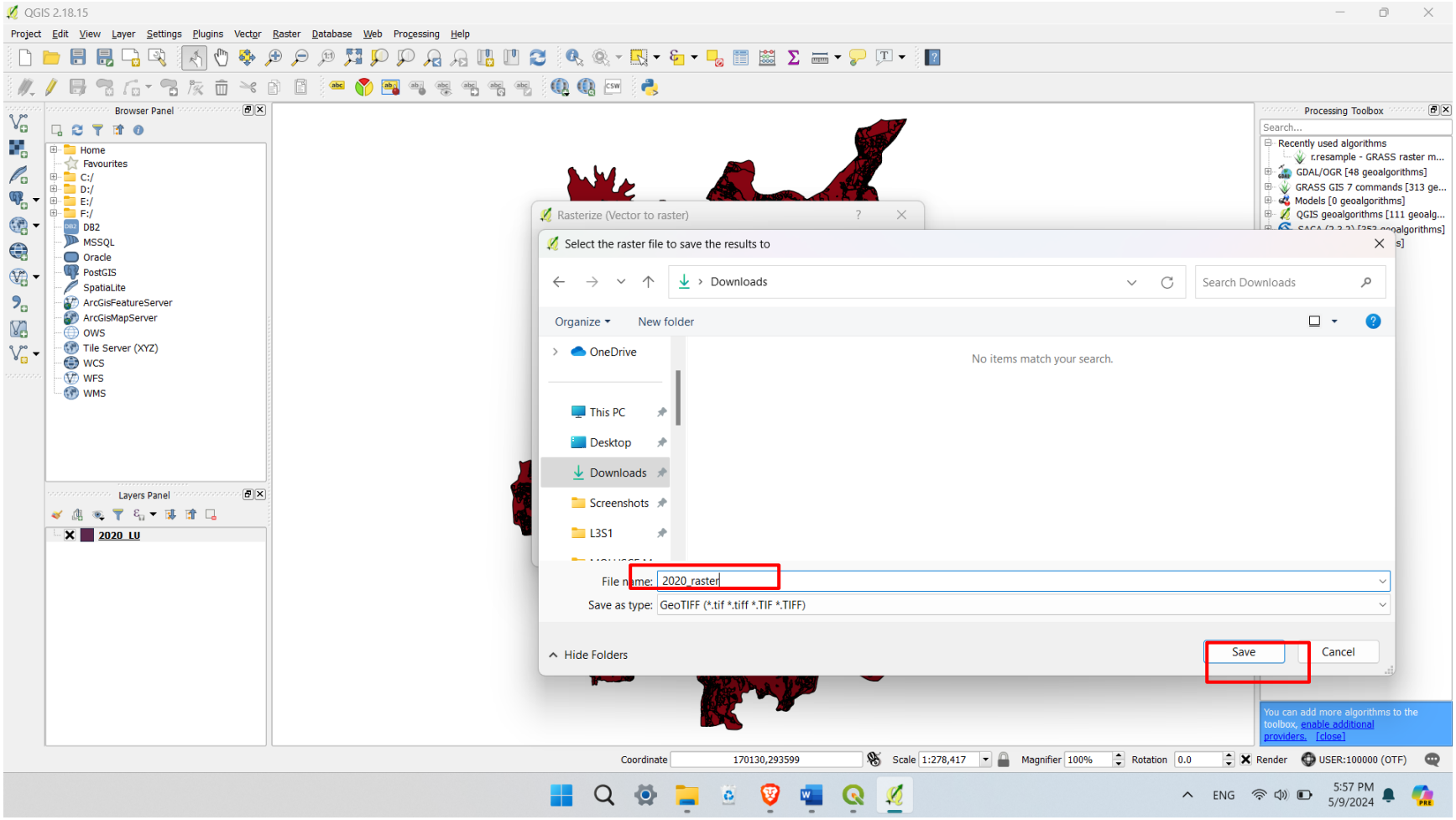
- As selected in QGIS version 3.22.7, select the "**LU**" field here as well.



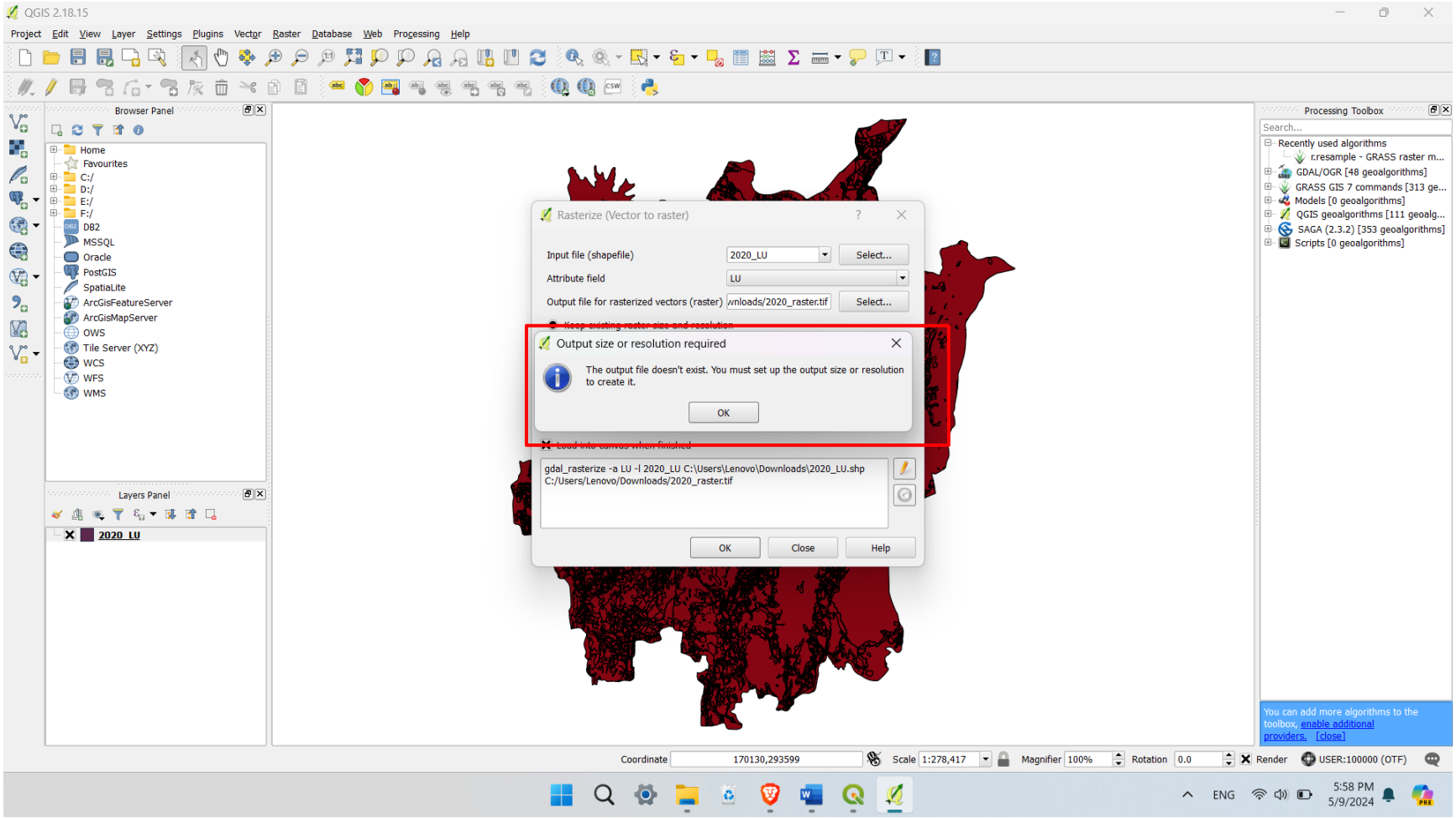
- The selected field will be shown as follows.
- Next, click on “**Select**” to browse a location for the saving results.



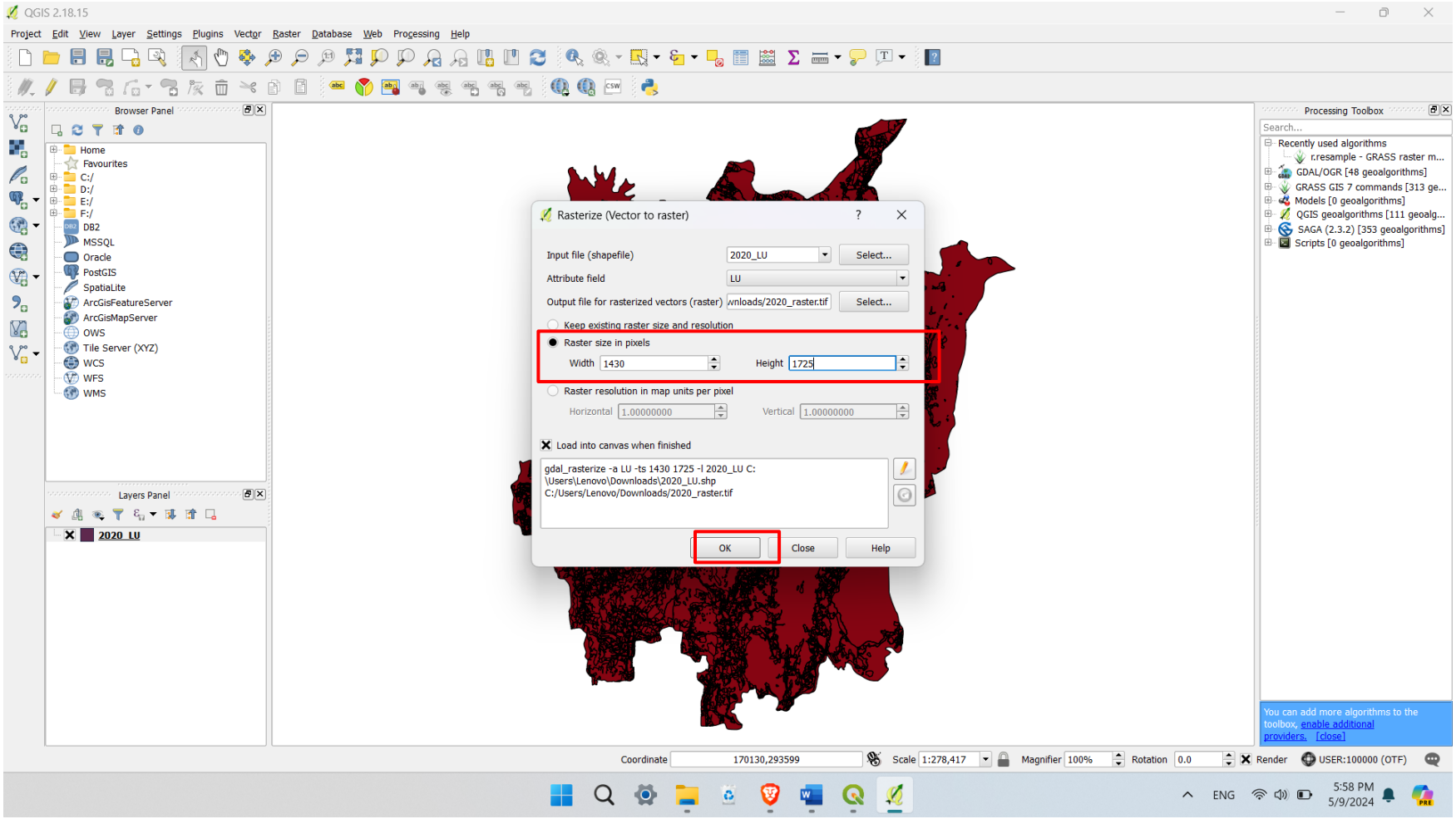
- Then, the following window will open on the screen. Select a suitable location as your preference and give a **file name**.
- Click on "**Save**".



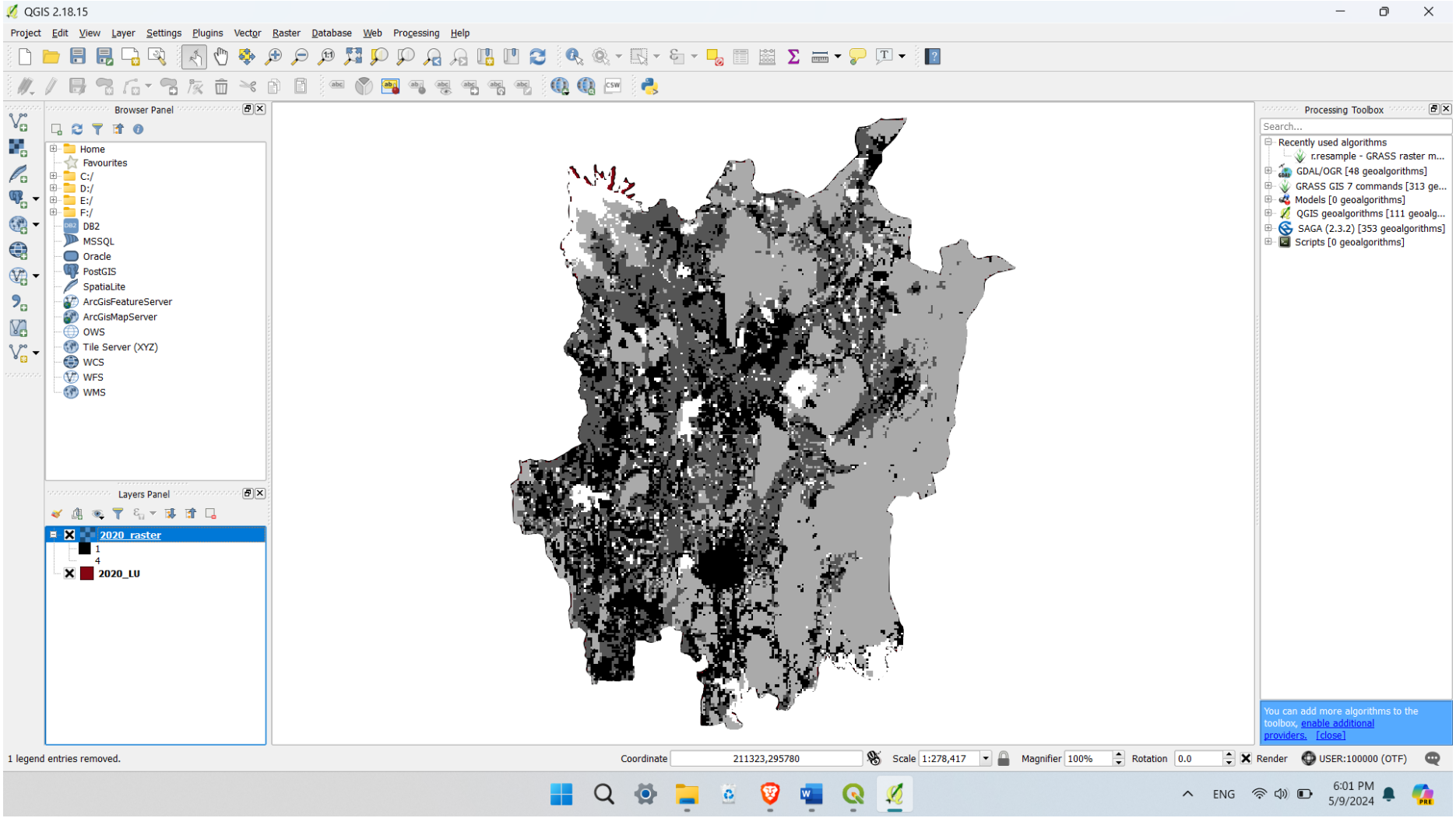
- The following warning message will appear on the screen. According to that, you have to set up the output resolution as you need for the raster layer.
- Click on “**OK**” to proceed to set up the resolution.



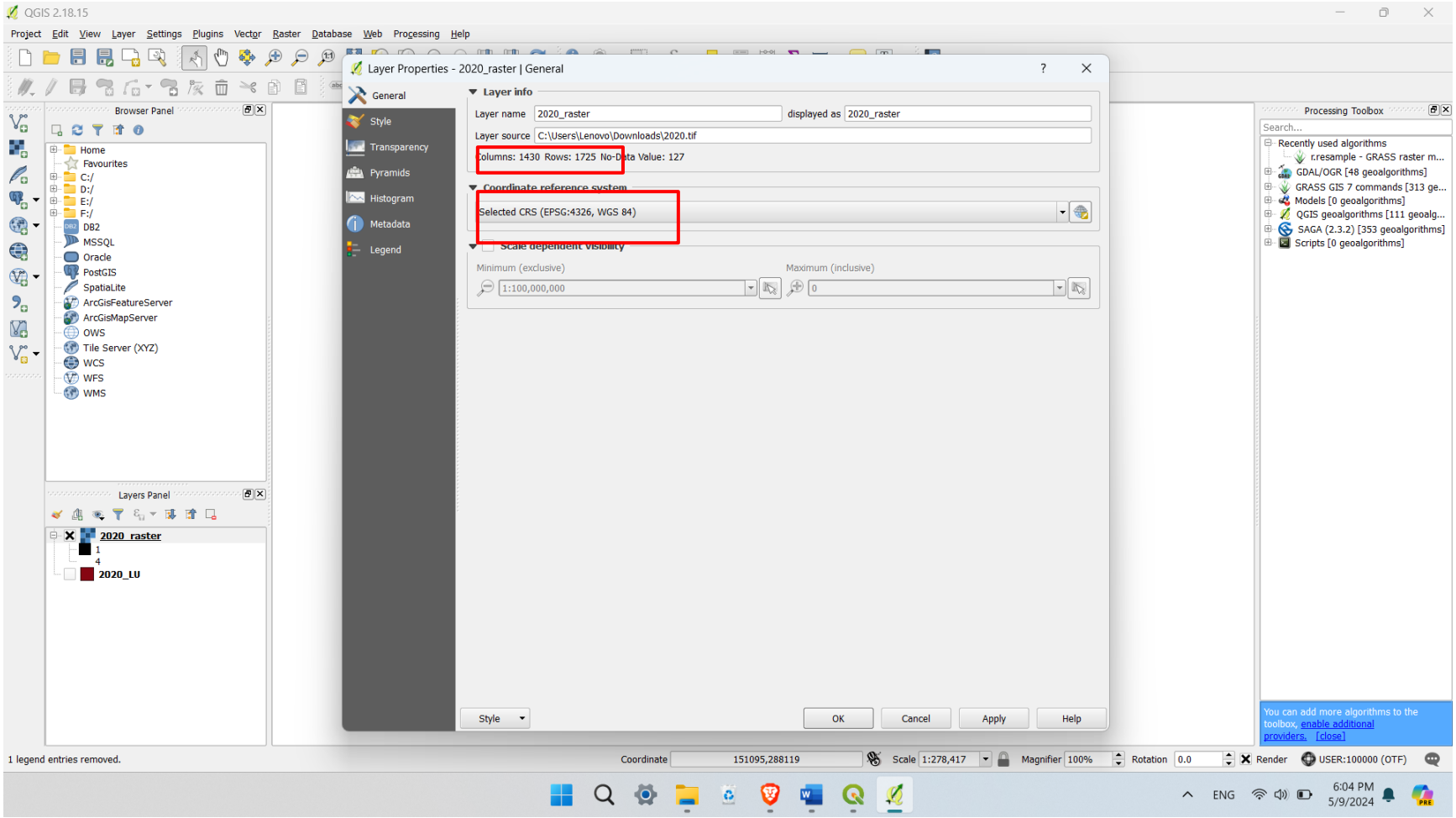
- Set up the values here as same as before.
- Click on “**OK**” to run the tool.



- The rasterized layer will appear on the screen as follows.

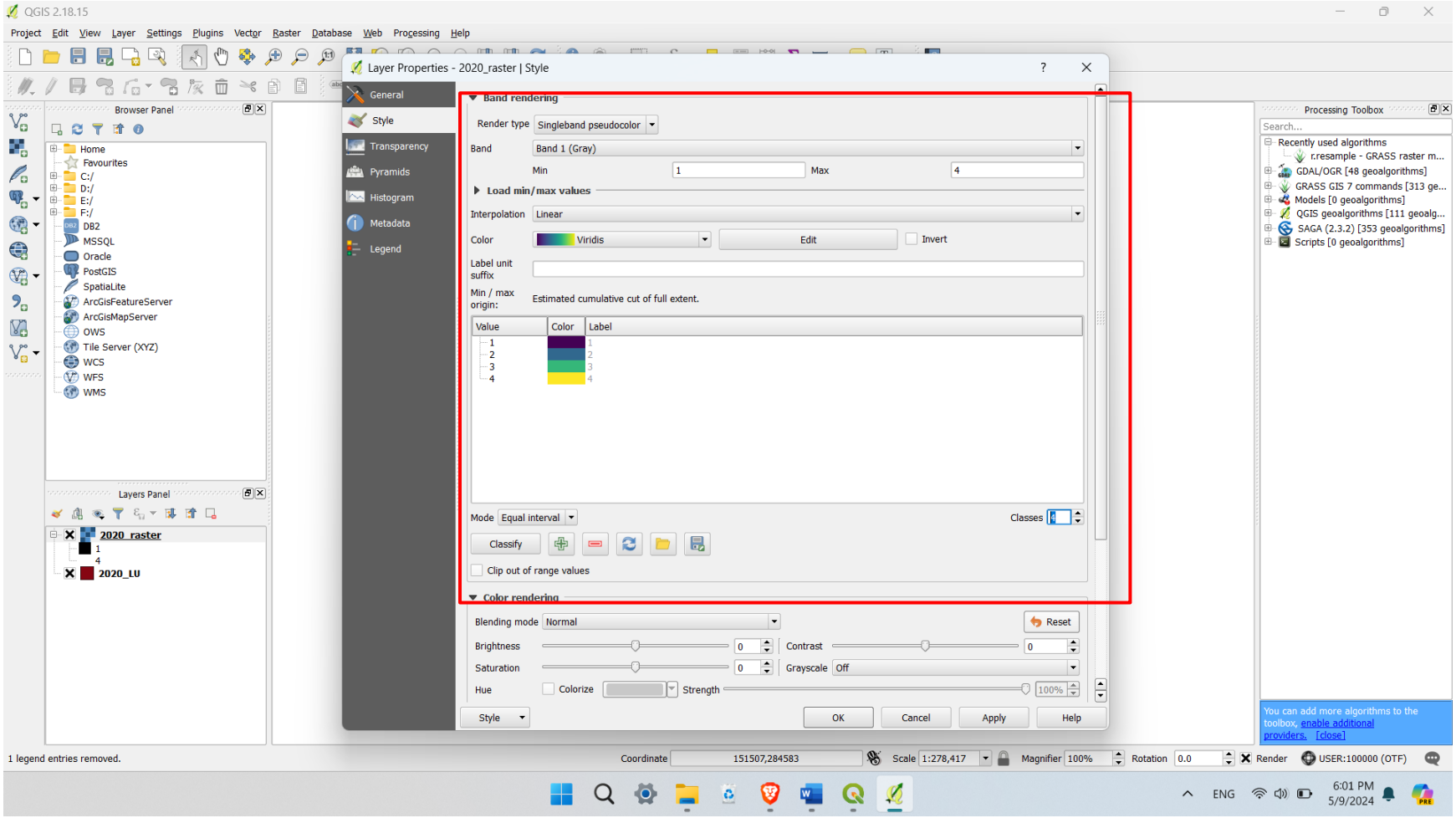


- Right-click on the layer and open the layer properties as follows.
- Under the **general properties** of the layer, now you can check the **columns and rows** values and the **coordinate reference system**.

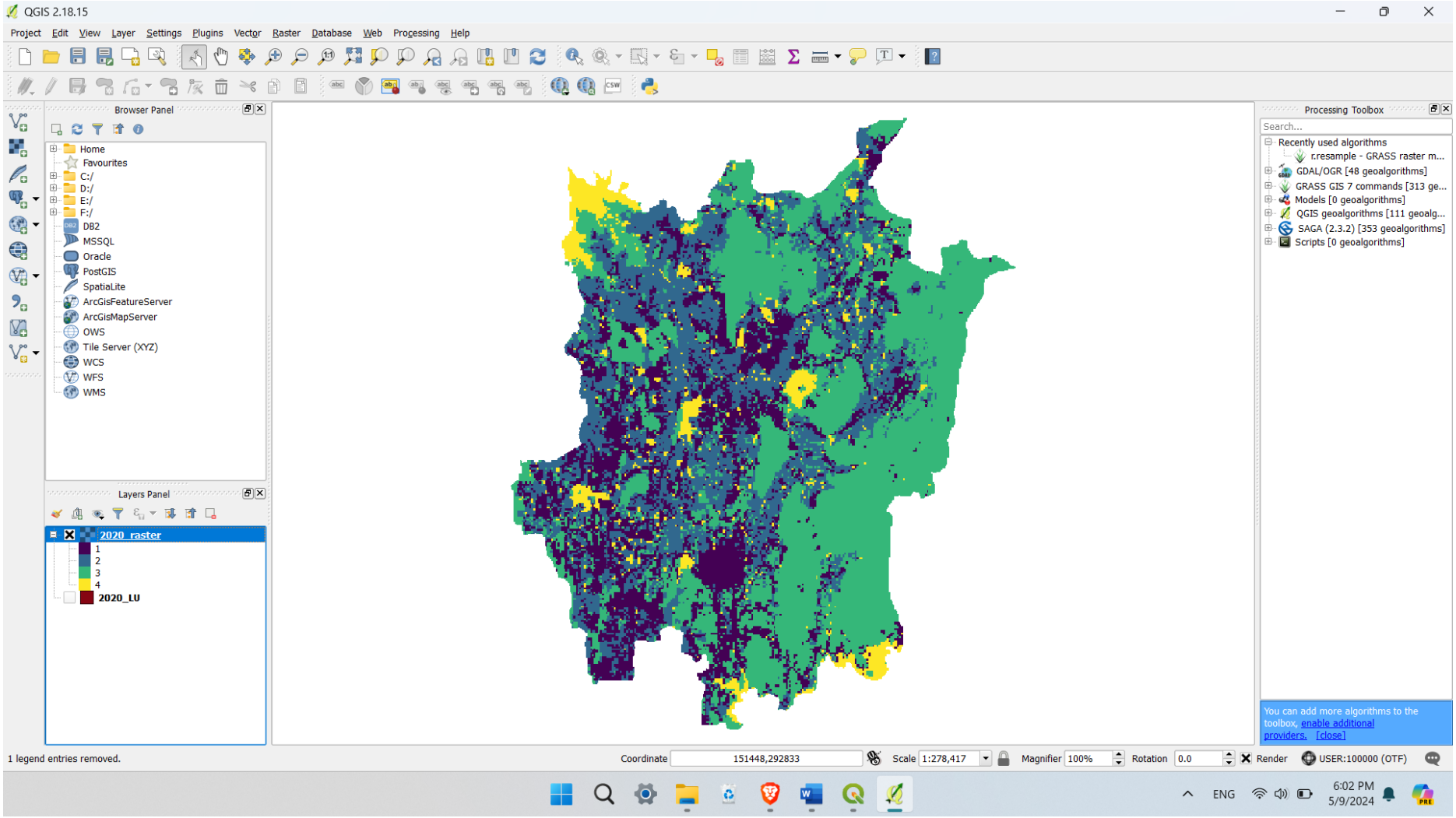


- Go to the **style properties** and set up the following settings as same as before in the QGIS 3.22.7.

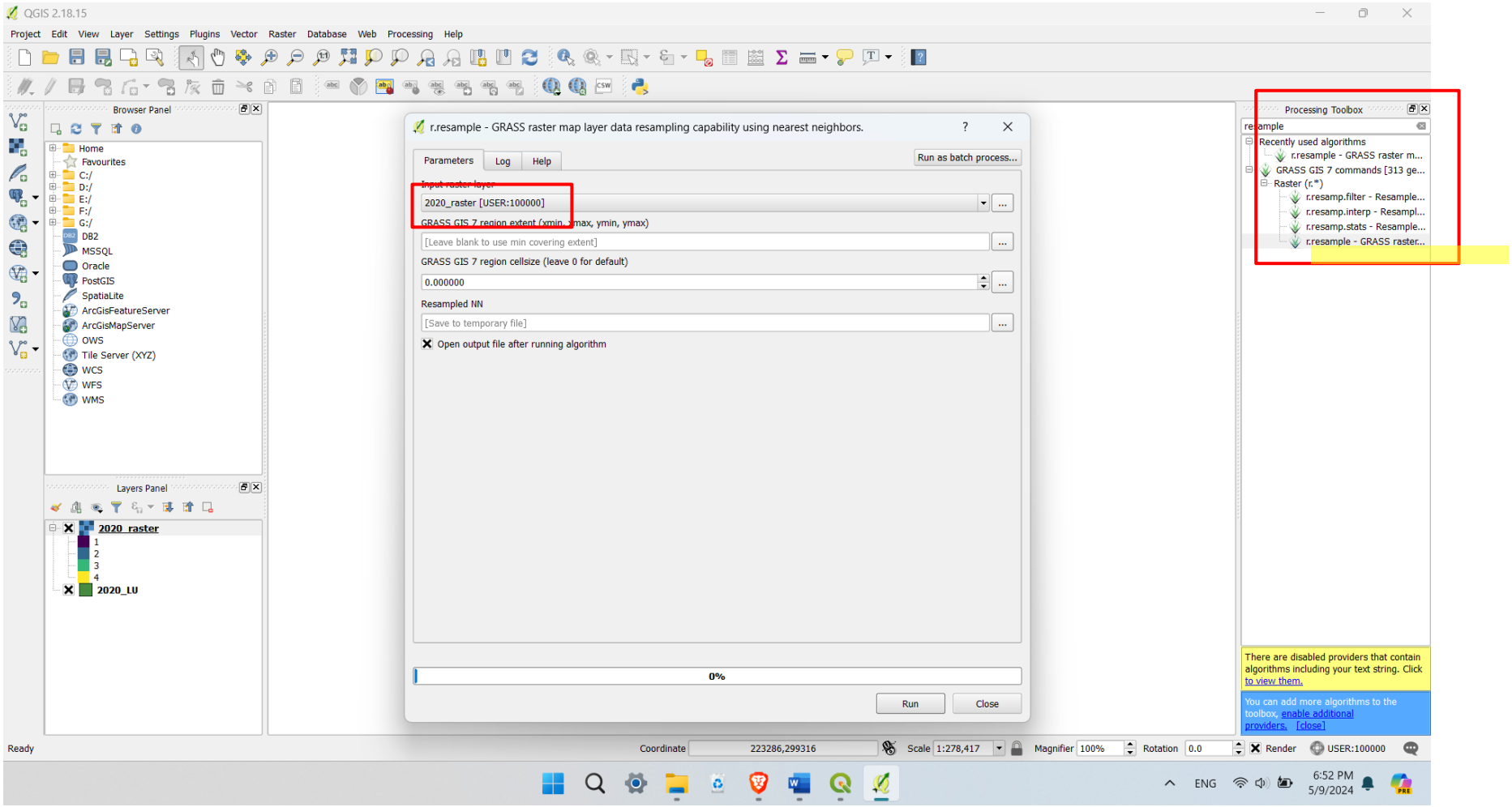
- This will provide a clear color combination to easily identify the land use categories.



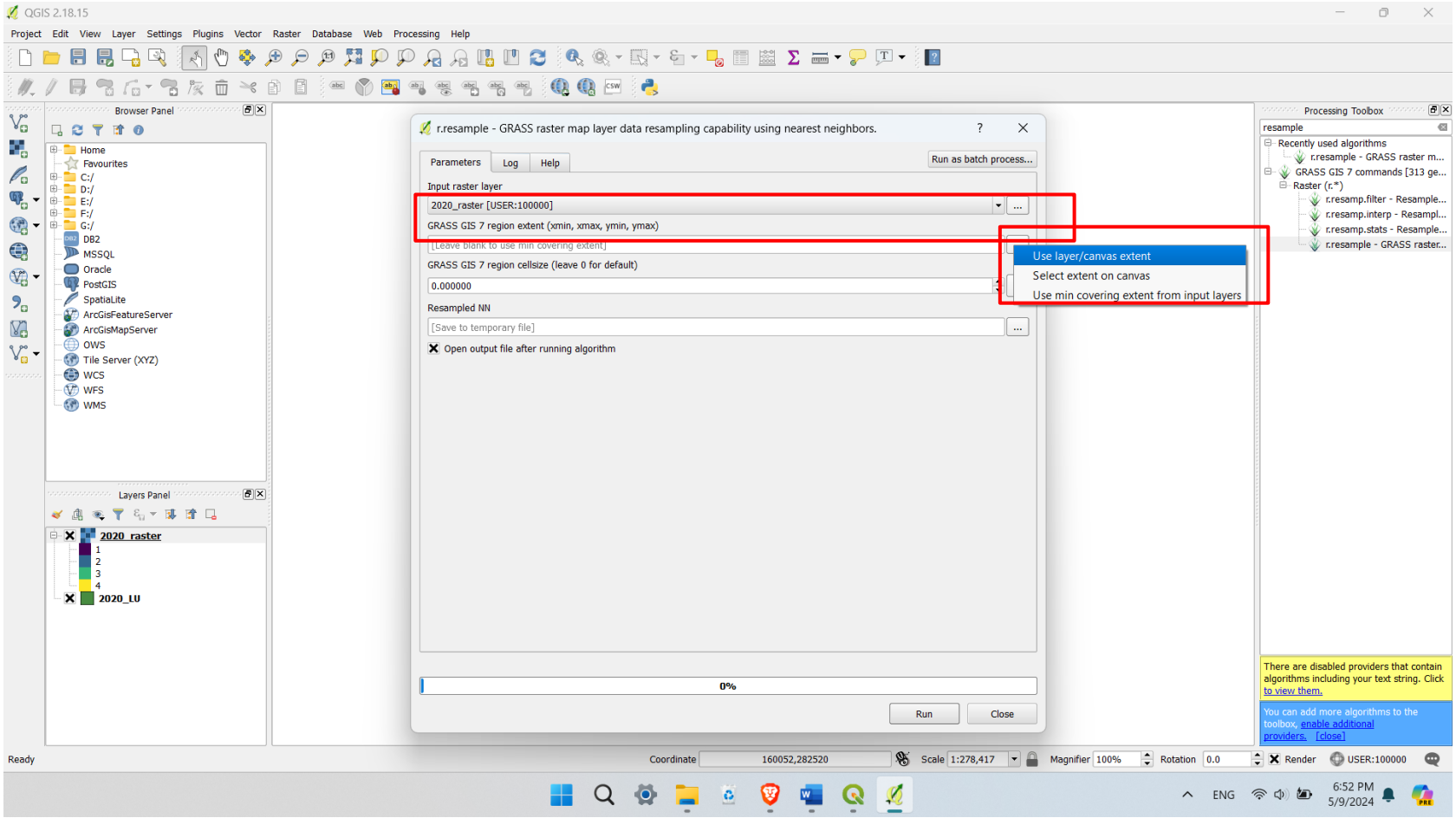
- The raster layer will appear on the screen with the new color combination as follows.



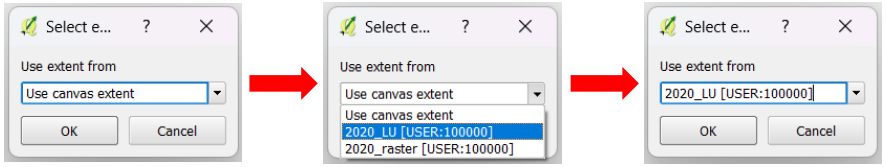
- In the next step, we have to set up the cell size. For that, search for the "**resample**" tool in the processing toolbox.
- Select the newly rasterized layer as for the "**Input raster layer**" here.



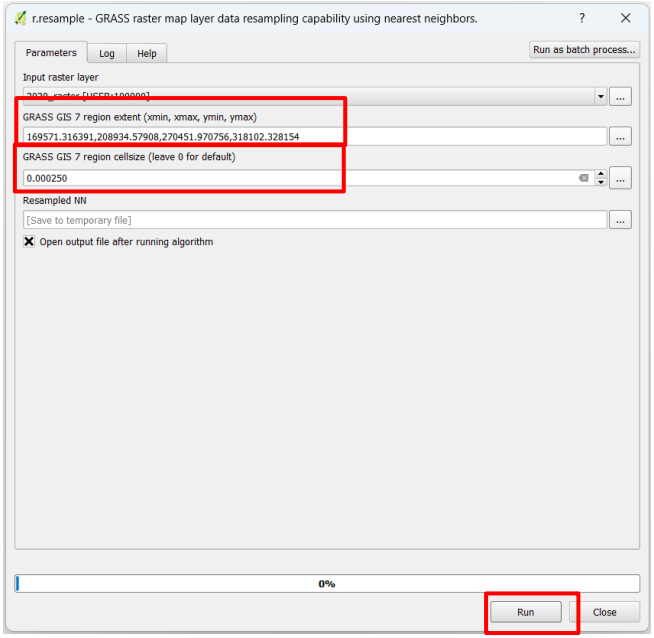
- Next, we have to set up the **region's extent**.
- For that, click on the icon that contains 3 dots, and click on "**Use layer/canvas extent**".



- Then, the following window will appear on the screen.
- Expand the list and select the layer that you want to use as the region extent for this raster layer.
- This extent of the region will be used for the extent of the new raster layer during the resampling process.



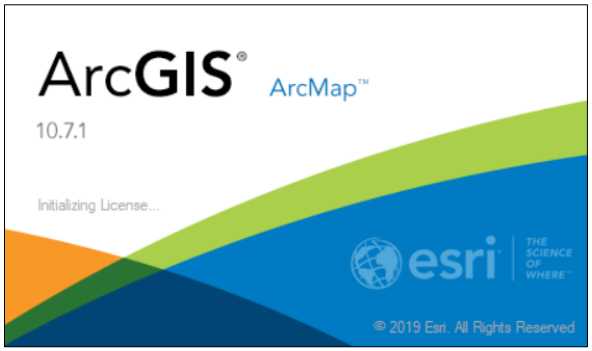
- The extent will be shown as follows.
- Next, enter the cell size that you want. After that, click on "**Run**" to proceed.



Rasterization with ArcMap

ArcMap is a comprehensive Geographic Information System (GIS) software developed by Esri, widely used for mapping and spatial analysis. It is not open-source software; rather, it is a commercial product that requires a license for use. Despite this, it is renowned for its robust features, ease of use, and extensive support and documentation.

Converting a vector layer to a raster layer can indeed vary in complexity between different GIS software. ArcMap generally offers a more user-friendly experience for this process compared to QGIS, primarily due to its more streamlined and integrated toolset. ArcMap's interface and tools are designed to facilitate easier conversion and resampling with fewer steps and more intuitive options.



On the other hand, QGIS, being an open-source platform, sometimes presents challenges with tool consistency and ease of use. While QGIS has made significant improvements over the years and offers robust functionality, some users may encounter issues such as tool compatibility, less intuitive workflows, and occasional bugs during conversion and resampling processes. QGIS's flexibility and extensive plugin ecosystem, including tools like MOLUSCE, provide powerful capabilities for advanced users who are familiar with its interface. Additionally, QGIS's open-source nature means that it is continually evolving, with a strong community contributing to its development and troubleshooting issues.

While ArcMap might offer a more straightforward and user-friendly experience for converting vector layers to raster layers, QGIS remains a powerful alternative, especially for those who can navigate its more complex toolset. Since QGIS is an open-source software, here we tried to use it for the entire process. But for this, you can also use ArcMap software like this.

2.2 Preparation of the layers for spatial variables

This part is the most important part of this analysis. Because the prediction of future land use change depends on these layers. In the area that we took as the sample study area, from 2005 to 2020, the reasons that affected the change in its land use should be considered here. Generally, some reasons mainly affect the rapid changes in land use of a particular area.

- **Warfare and Armed Conflict**
- **Economic Crises and Institutional Overhaul**
- **Population Growth and Urbanization**
- **Technological Advancements and Infrastructure Development**
- **Climate Change and Natural Disasters**
- **Policy and Land Reforms**
- **Technological Diffusion and Innovation**

Rapid changes in land use happen because of different reasons, both natural and man-made. One big reason is warfare and armed conflict. When there's fighting, it affects places where lots of people live, no matter what kind of land it is. The effects of war on land can be different and can last a long time.

Another big reason is when there are economic problems or big changes in how things are run. When money gets tight or when there are big changes in how the government works, it can suddenly change how land is used. For example, it might lead to things like cutting down trees illegally or changing from growing crops for money to growing food to eat at home.

Then there's population growth and cities getting bigger. More people need more land, so places where food is grown might get turned into cities. When new roads or buildings are built, it changes the land too. Climate change and disasters like floods or wildfires can mess up the land. All these things, plus rules about land and new technologies, like better ways to grow crops or use solar power, all play a big part in how land is used.

In the case of **Dambulla**, during the period considered above, no special reason has affected the land use of the area. But with the development of the country during the considered period (infrastructure development related to transportation, housing, agriculture, etc.), the built-up area of this region has increased significantly; especially the Municipal Council area. Population growth and rapid urbanization must be another reason for this.

According to our collective studies of the Dambulla area, these were identified as factors that somehow influenced its land use change between 2005 and 2020.

1. **Environmentally sensitive areas**
2. **Road density**
3. **Euclidean distances between roads**
4. **Euclidean distances to the nearest town centers**
5. **Population density**
6. **Access to services**
7. **Accessibility**
8. **Land use efficiency**
9. **Building density**

Separate layers should be created for each of these factors, and their rows, columns, and geometries should be the same as the previously created land use layers. If there is any problem and it is not the same, then the mistakes should be corrected as mentioned before. Next, let's see how we can create raster layers for these spatial variables. There are 9 variables shown here, and how to prepare the required raster layers for the following spatial variables is presented in several separate books.

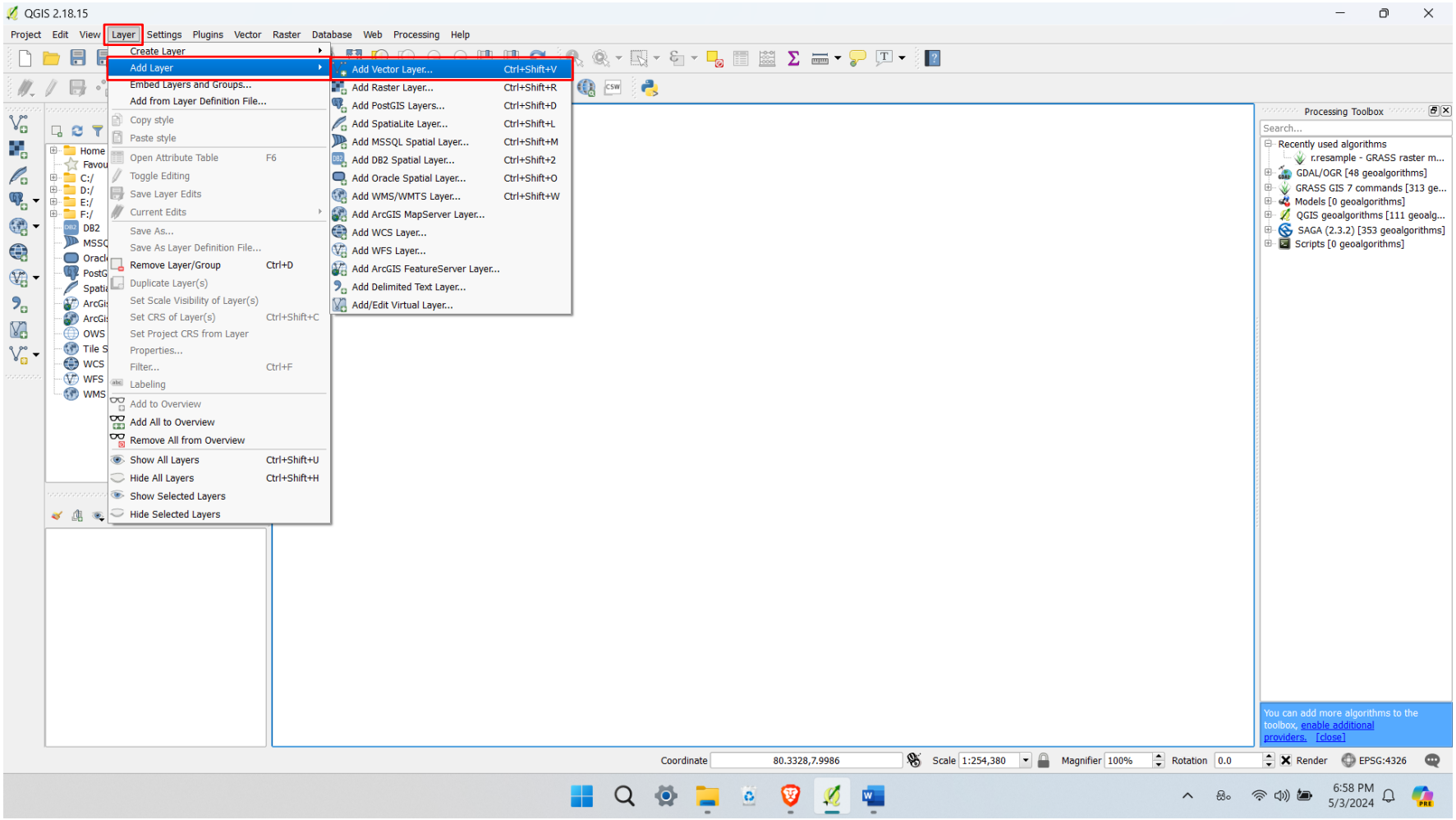
- **Land use efficiency** (Refer to the book)
- **Building density** (Refer to the book)

1. Environmentally sensitive areas

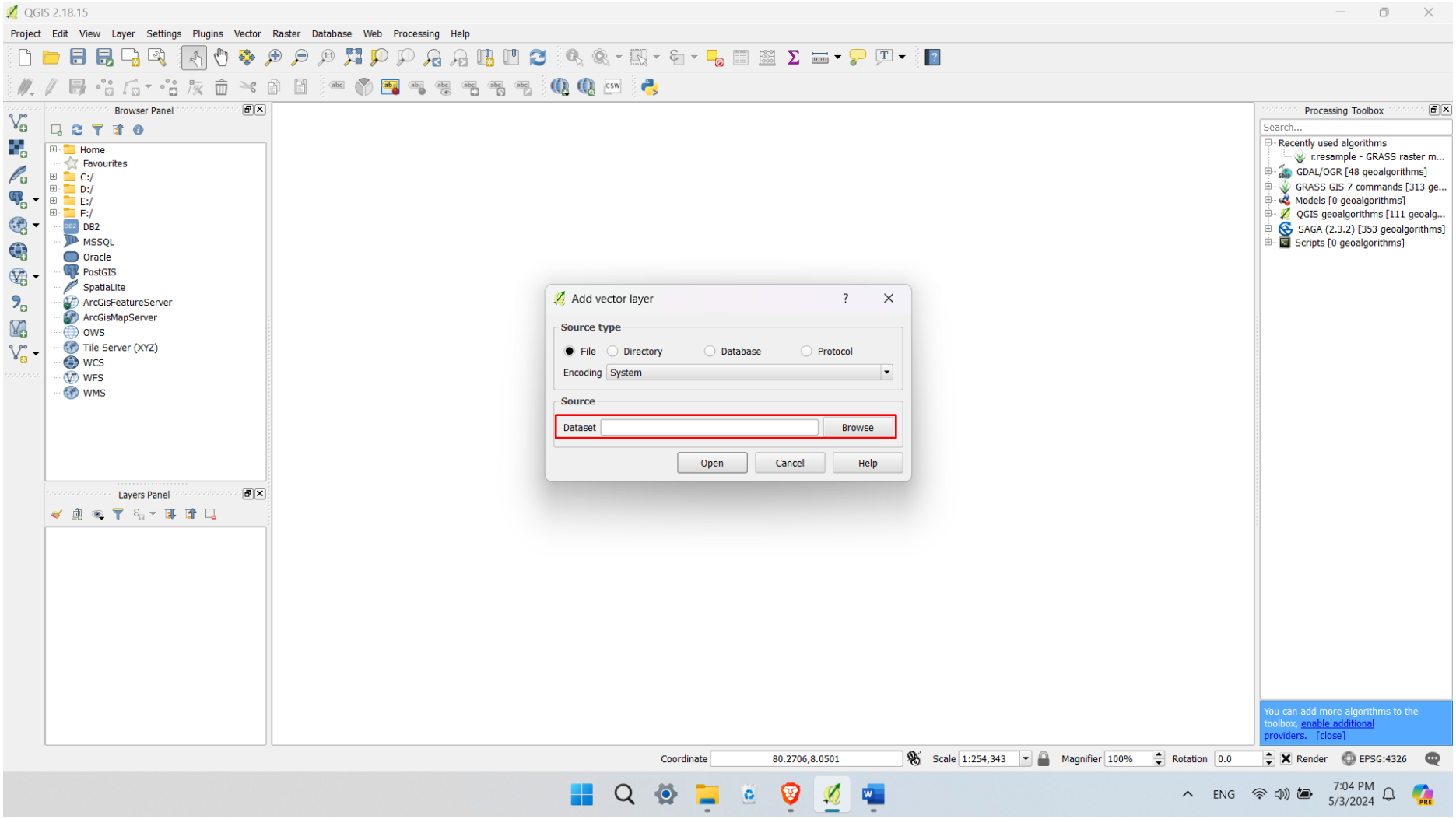
Here we use the “environmentally sensitive areas” of the area which is considered as a spatial variable. Generally, environmentally sensitive areas are protected by the government. Also, no permission is given for construction in those areas. To create this layer, first, open the land use layer of the Dambulla area.

1. Click on the “**Layer**” on the main toolbar and open the layer toolbar.
2. Then, click on “**Add Layer**”.

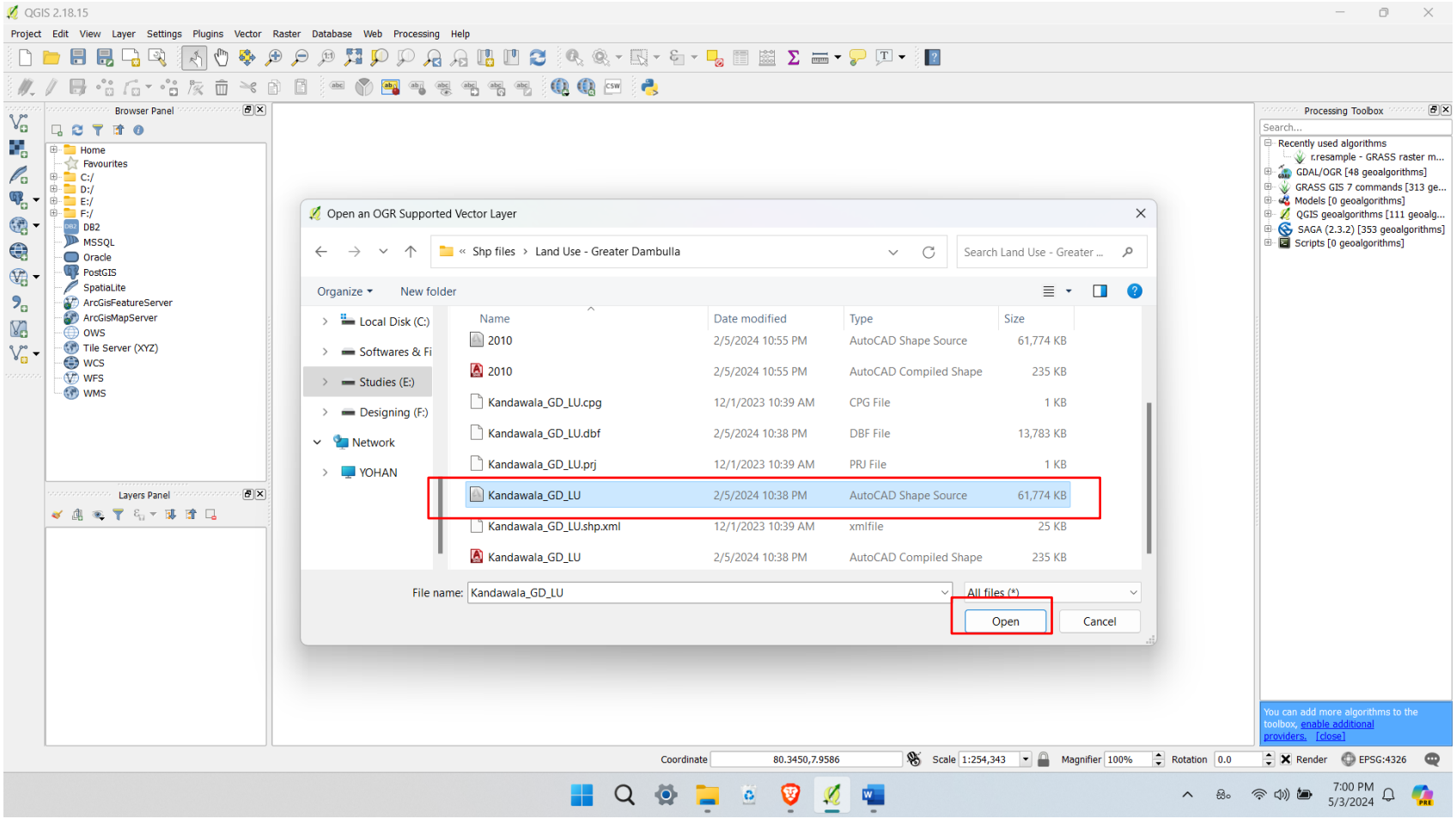
3. Next, click on “**Add Vector Layer**”.



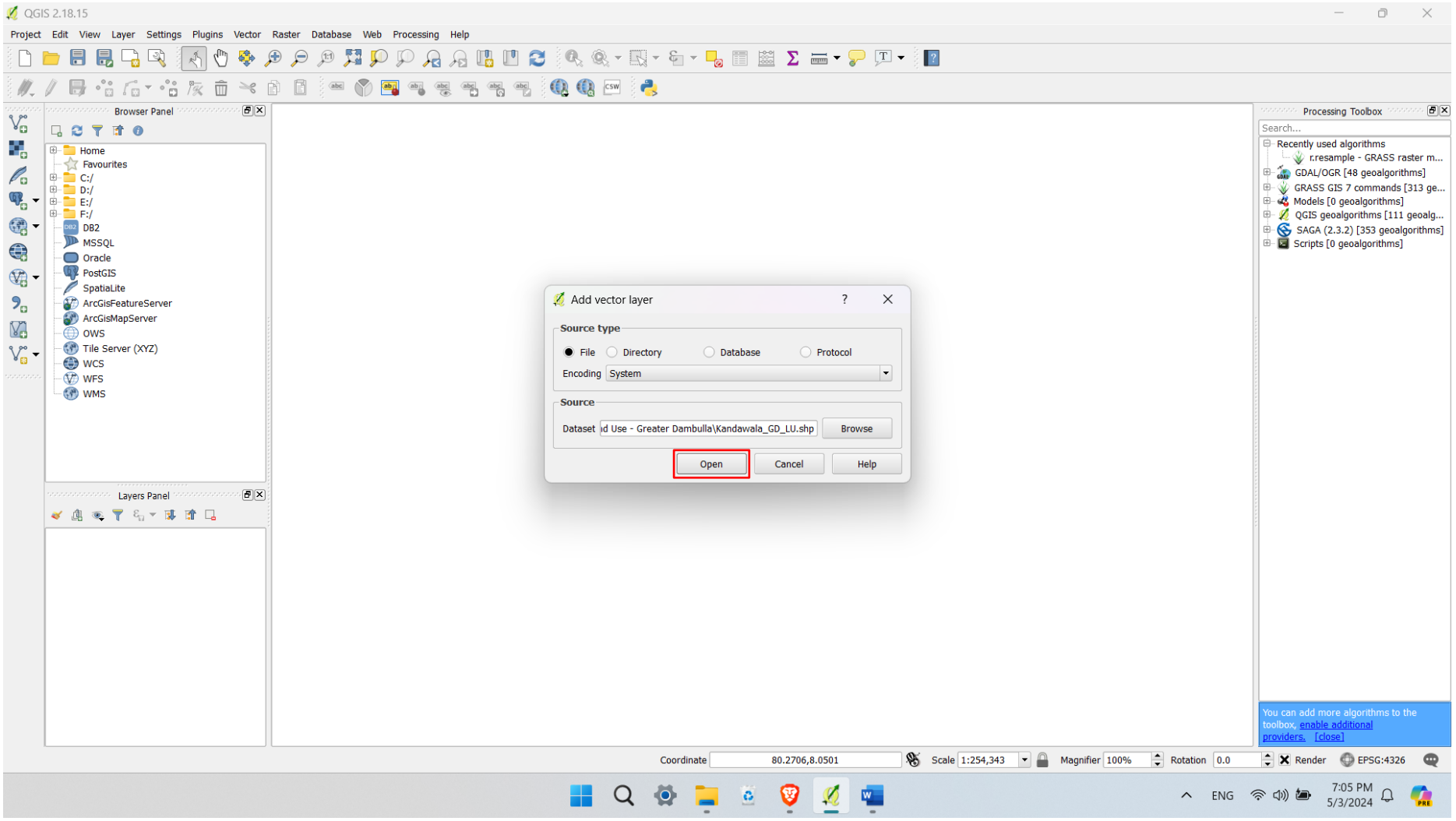
Now, the following window will appear on the screen and you can browse the vector file that you want to open.



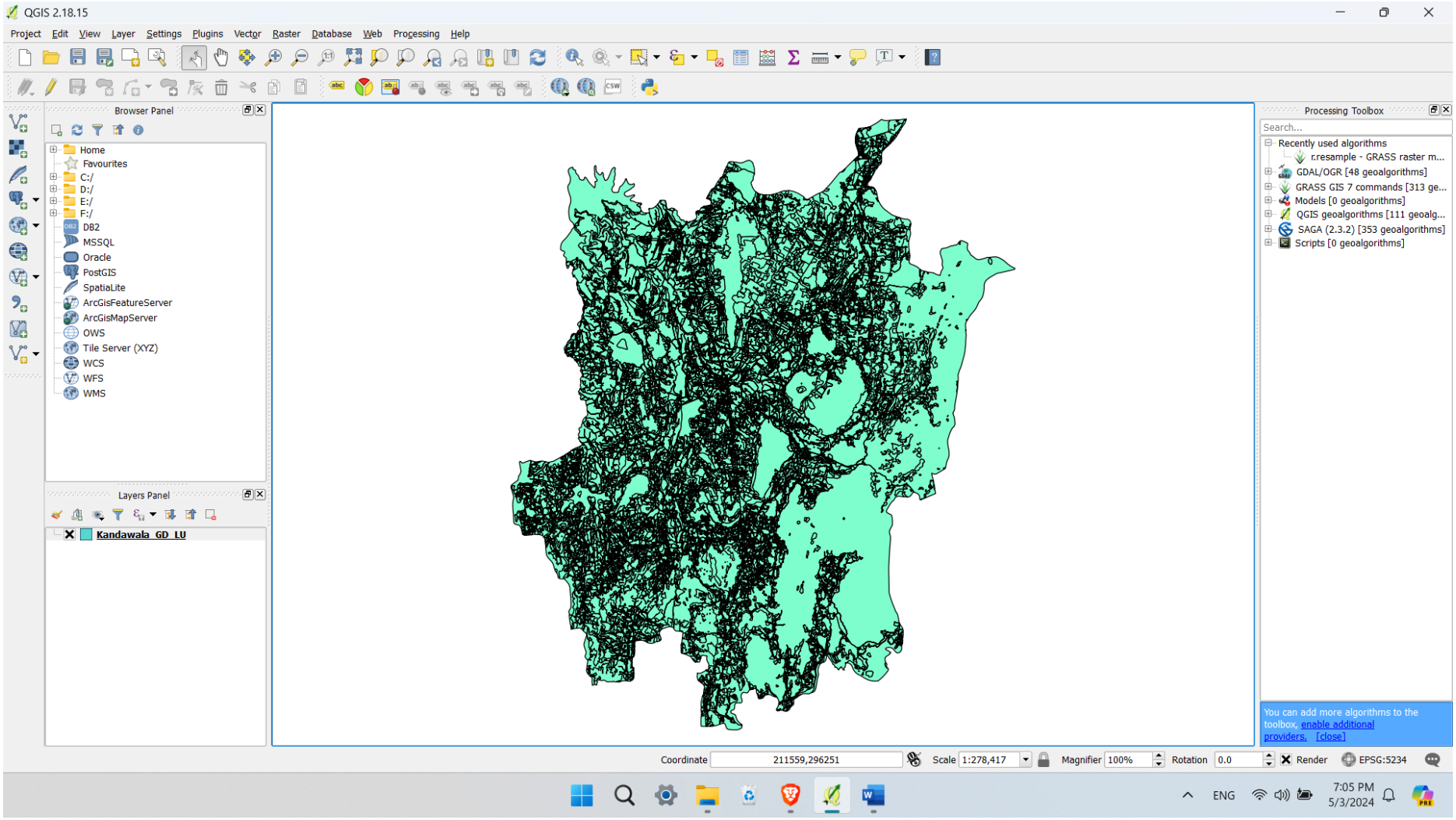
After clicking on “**Browse**”, the following window will open. Then, go to the relevant folder and select the vector file. Usually, a shape file consists of 6 other files. The file type you should choose to open here is the "**AutoCAD Shape Source**" file. As per the instructions, click on that layer, and after that click on “**Open**”.



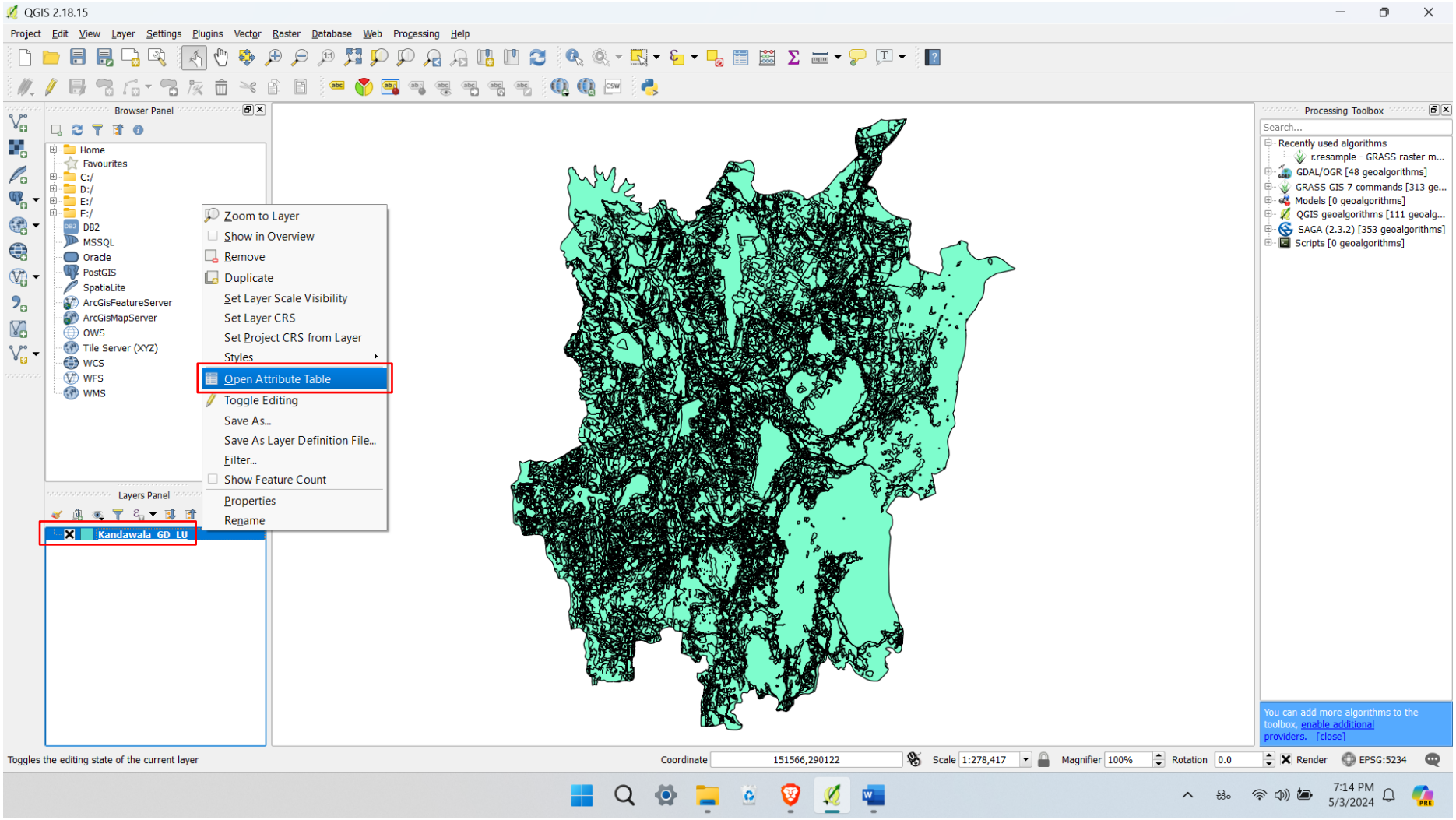
Again, click on “**Open**” to add the layer to the workspace.



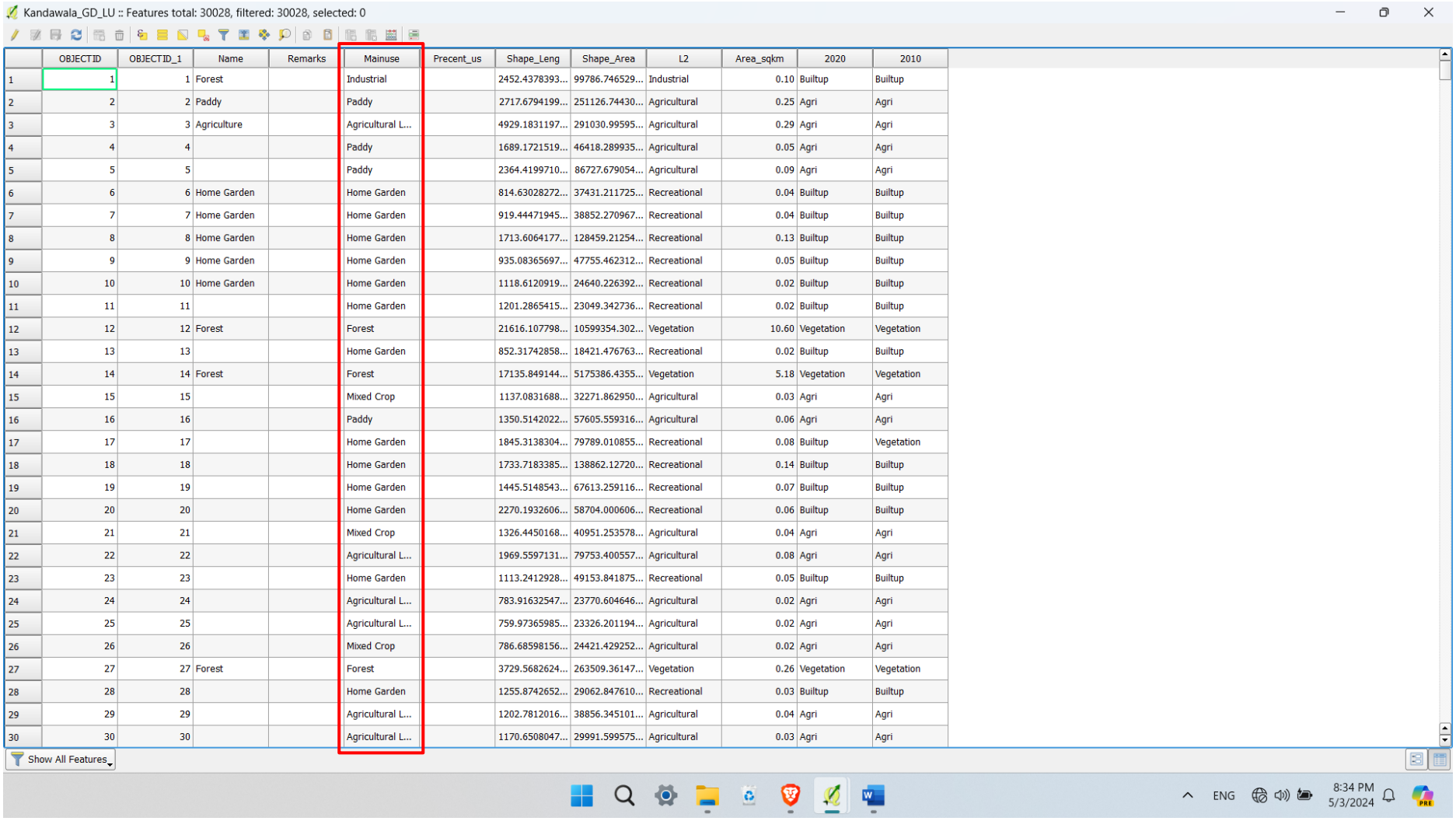
The land use layer will appear on the screen as follows.



Now, right-click on the layer and click on “**Open Attribute Table**”.



The Attribute Table of the layer will open as follows. Under the column “**Mainuse**”, we can see the land use of every plot of the Dambulla regional area.



	OBJECTID	OBJECTID_1	Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2	Area_sqkm	2020	2010
1	1	1	Forest		Industrial		2452.4378393...	99786.746529...	Industrial	0.10	Builtup	Builtup
2	2	2	Paddy		Paddy		2717.6794199...	251126.74430...	Agricultural	0.25	Agri	Agri
3	3	3	Agriculture		Agricultural L...		4929.1831197...	291030.99595...	Agricultural	0.29	Agri	Agri
4	4	4			Paddy		1689.1721519...	46418.289935...	Agricultural	0.05	Agri	Agri
5	5	5			Paddy		2364.4199710...	86727.679054...	Agricultural	0.09	Agri	Agri
6	6	6	Home Garden		Home Garden		814.63028272...	37431.211725...	Recreational	0.04	Builtup	Builtup
7	7	7	Home Garden		Home Garden		919.44471945...	38852.270967...	Recreational	0.04	Builtup	Builtup
8	8	8	Home Garden		Home Garden		1713.6064177...	128459.21254...	Recreational	0.13	Builtup	Builtup
9	9	9	Home Garden		Home Garden		935.08365697...	47755.462312...	Recreational	0.05	Builtup	Builtup
10	10	10	Home Garden		Home Garden		1118.6120919...	24640.226392...	Recreational	0.02	Builtup	Builtup
11	11	11			Home Garden		1201.2865415...	23049.342736...	Recreational	0.02	Builtup	Builtup
12	12	12	Forest		Forest		21616.107798...	10599354.302...	Vegetation	10.60	Vegetation	Vegetation
13	13	13			Home Garden		852.31742858...	18421.476763...	Recreational	0.02	Builtup	Builtup
14	14	14	Forest		Forest		17135.849144...	5175386.4355...	Vegetation	5.18	Vegetation	Vegetation
15	15	15			Mixed Crop		1137.0831688...	32271.862950...	Agricultural	0.03	Agri	Agri
16	16	16			Paddy		1350.5142022...	57605.559316...	Agricultural	0.06	Agri	Agri
17	17	17			Home Garden		1845.3138304...	79789.010855...	Recreational	0.08	Builtup	Vegetation
18	18	18			Home Garden		1733.7183385...	138862.12720...	Recreational	0.14	Builtup	Builtup
19	19	19			Home Garden		1445.5148543...	67613.259116...	Recreational	0.07	Builtup	Builtup
20	20	20			Home Garden		2270.1932606...	58704.000606...	Recreational	0.06	Builtup	Builtup
21	21	21			Mixed Crop		1326.4450168...	40951.253578...	Agricultural	0.04	Agri	Agri
22	22	22			Agricultural L...		1969.5597131...	79753.400557...	Agricultural	0.08	Agri	Agri
23	23	23			Home Garden		1113.2412928...	49153.841875...	Recreational	0.05	Builtup	Builtup
24	24	24			Agricultural L...		783.91632547...	23770.604646...	Agricultural	0.02	Agri	Agri
25	25	25			Agricultural L...		759.97365985...	23326.201194...	Agricultural	0.02	Agri	Agri
26	26	26			Mixed Crop		786.68598156...	24421.429252...	Agricultural	0.02	Agri	Agri
27	27	27	Forest		Forest		3729.5682624...	263509.36147...	Vegetation	0.26	Vegetation	Vegetation
28	28	28			Home Garden		1255.8742652...	29062.847610...	Recreational	0.03	Builtup	Builtup
29	29	29			Agricultural L...		1202.7812016...	38856.345101...	Agricultural	0.04	Agri	Agri
30	30	30			Agricultural L...		1170.6508047...	29991.599575...	Agricultural	0.03	Agri	Agri

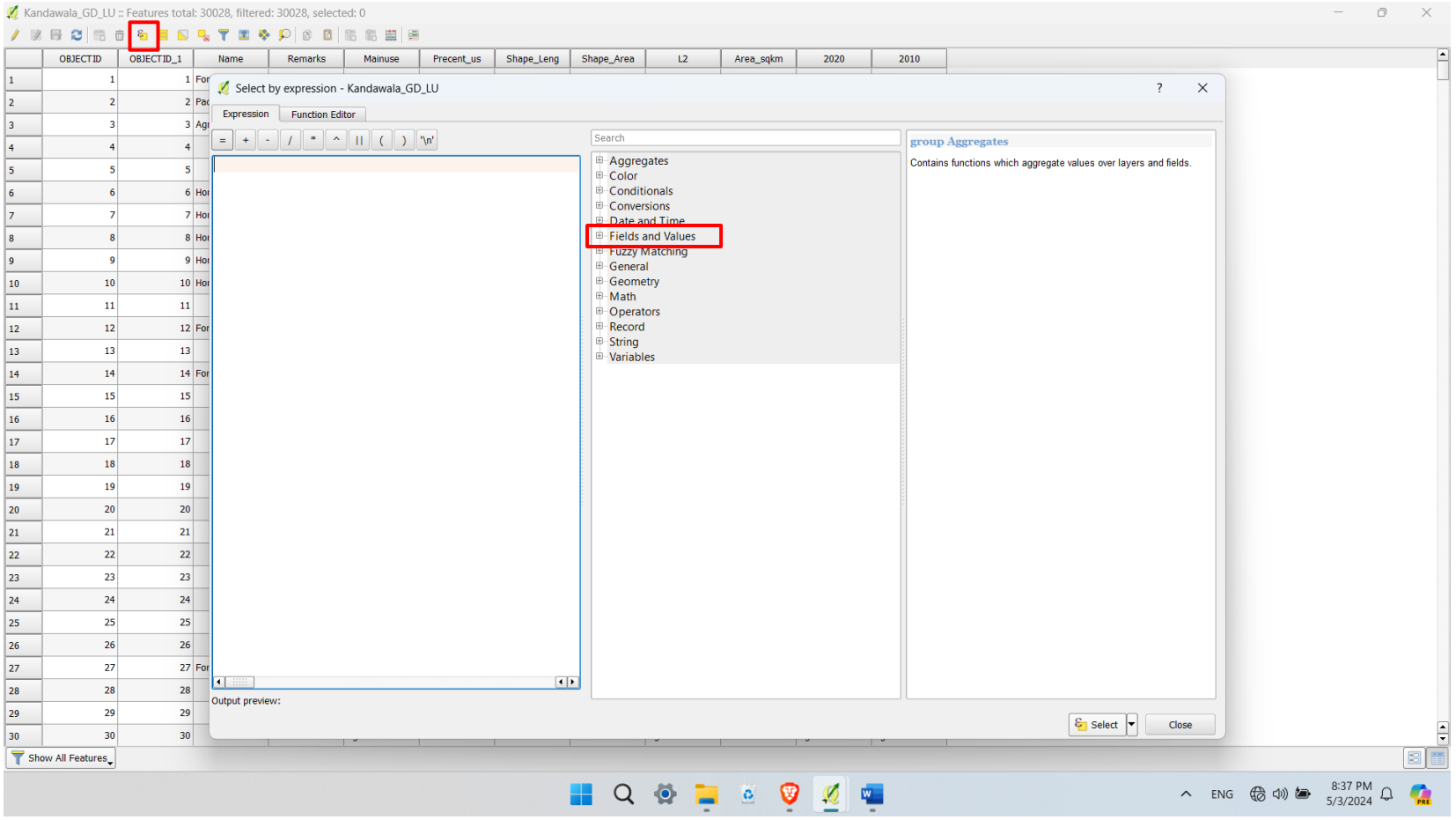
Considering these land use categories related to the Dambulla area, we divided their environmental sensitivity into 3 classes. This classification is based on the potential impact each land use category may have on the environment, considering factors such as habitat disturbance, biodiversity loss, pollution, and conservation importance.

Environmental Sensitivity of Greater Dambulla		
Low Environmental Sensitivity (1)	**Medium Environmental Sensitivity (2)**	**High Environmental Sensitivity (3)**
- Aviation - Bank and Allied - Commercial/Residential - Commercial - Dam - Educational - Grassland - Health - Home garden - Industrial - Institutional - Open space - Other plantation - Other roads - RDA road - Railway - Rock - Socio-cultural places - Sports and amusement - Stores and warehouse - Transportation - Under-construction sites - Utility - Vacant buildings - Unclassified areas	- Abandoned tank - Agricultural land - Coconut plantation - Mixed crop - Paddy fields - Plantations (other than coconut) - Religious place - Tourism - Vacant lands	- Archaeological places - Catchment area - Forest - Marshy - River - Scrub - Water bodies

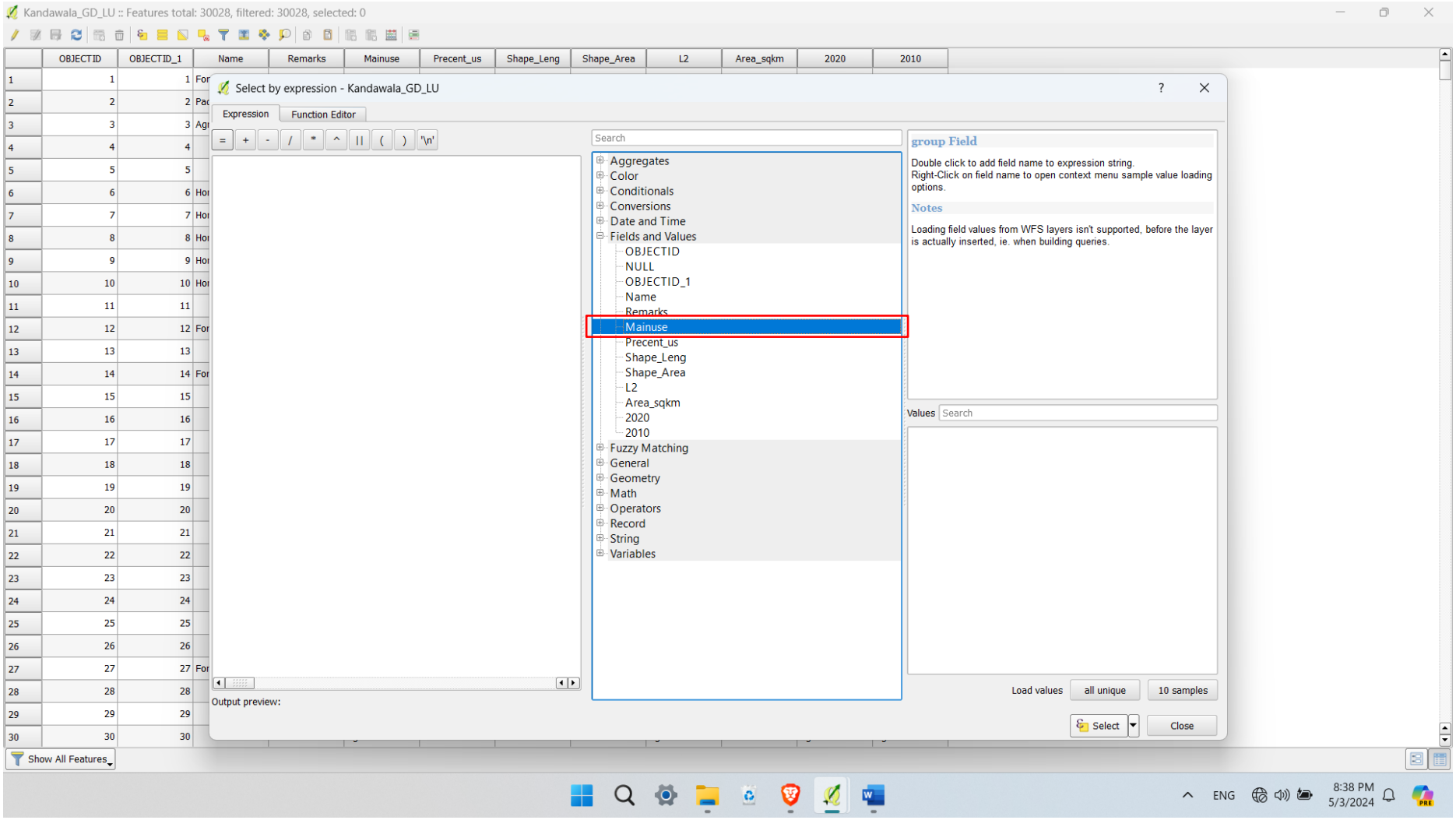
Table 5 -Categorization of the environmental sensitivity

Now we can check, how many land use categories are contained under the "**Mainuse**" column. For that,

1. Click on the "**Select by expression**" tool. Then, the following window will open.
2. Click on the "**+**" mark and expand the "**Fields and Values**". Or you can double-click on the "Fields and Values" to expand it.

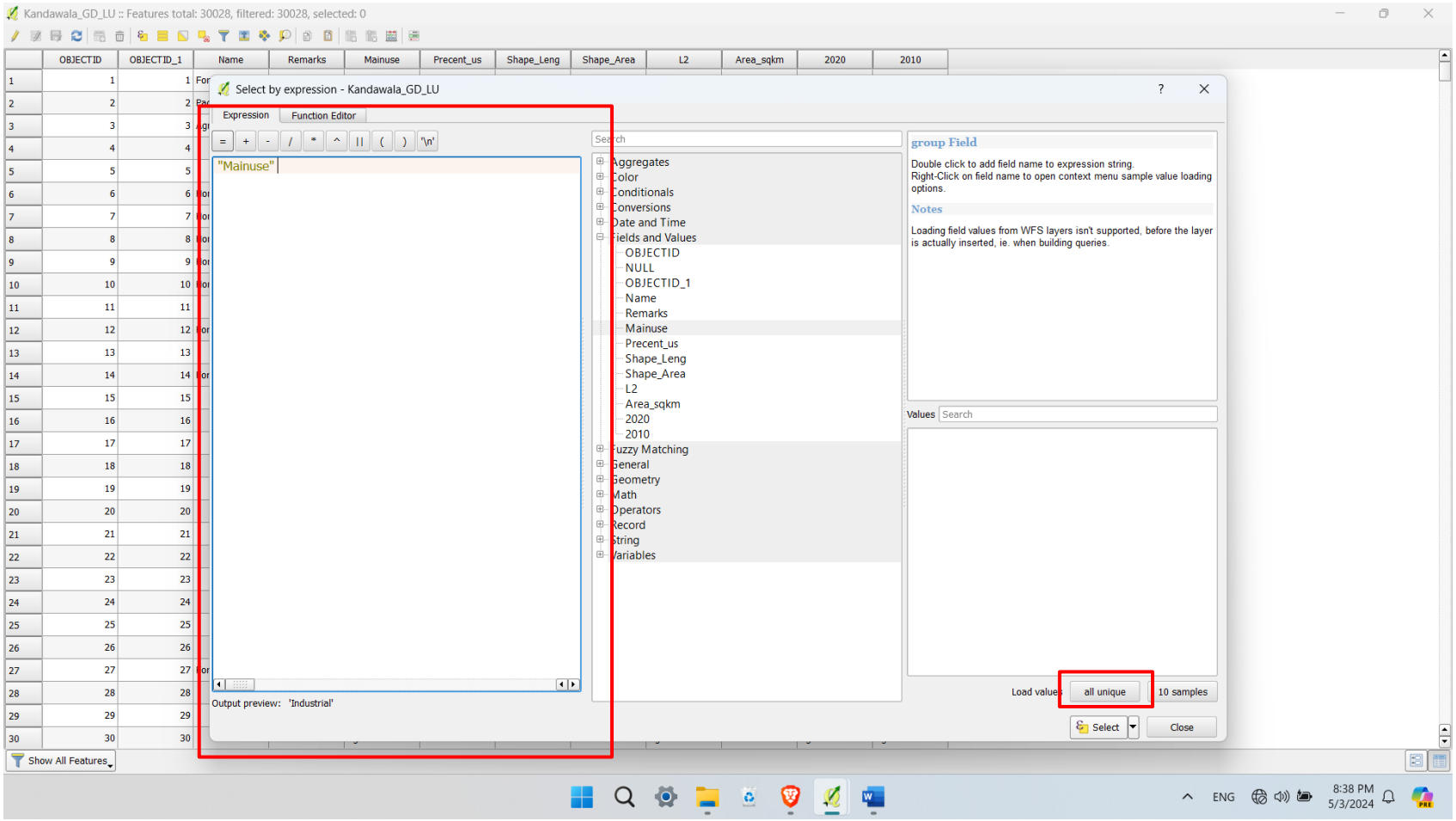


After that, double-click on “**Mainuse**” from the expanded list.

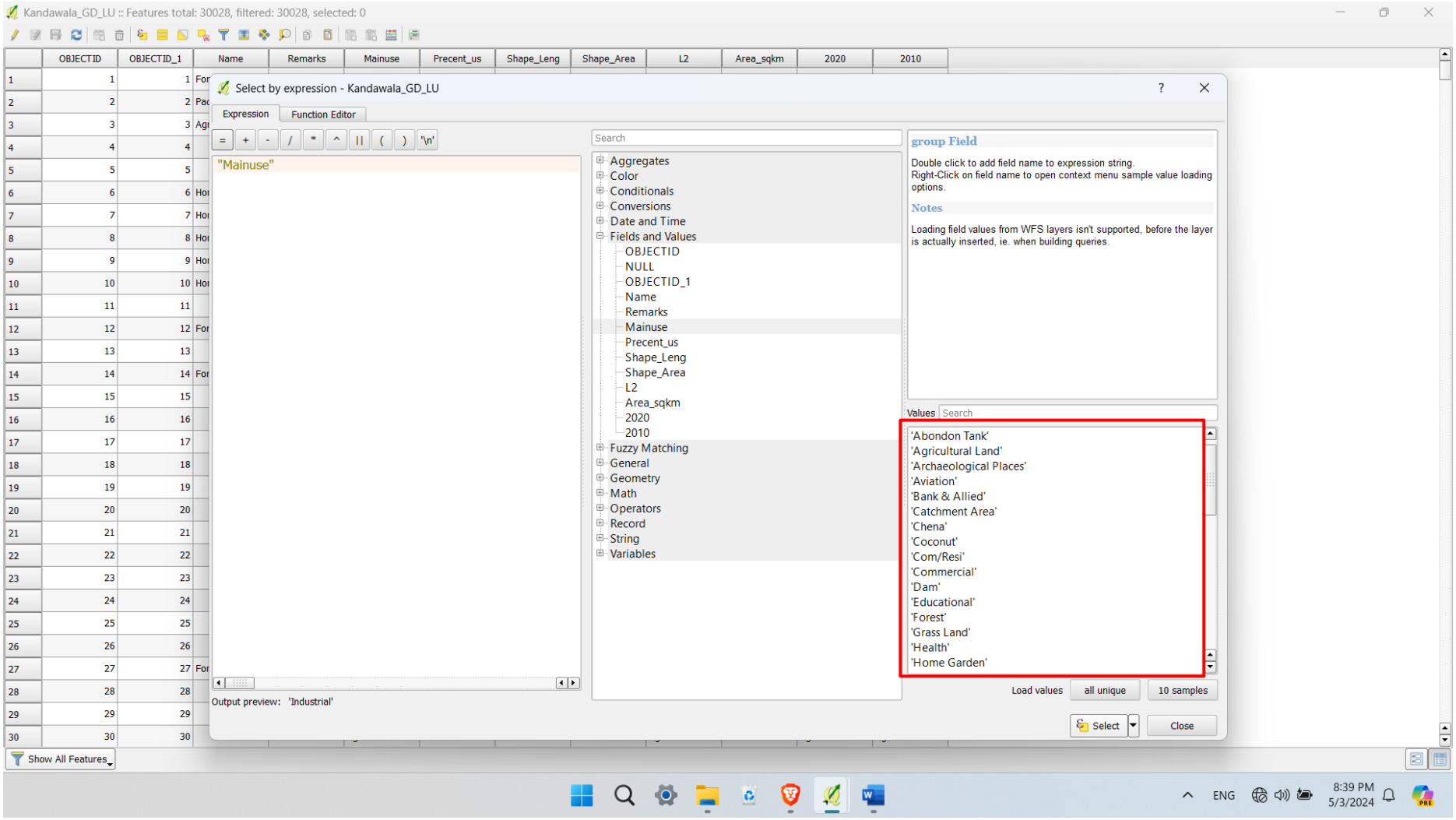


If you properly double-click on that, it will be shown in the expressions tab as follows.

- Then, click on “**all unique**”. It is used to see the all uniques under the selected field.

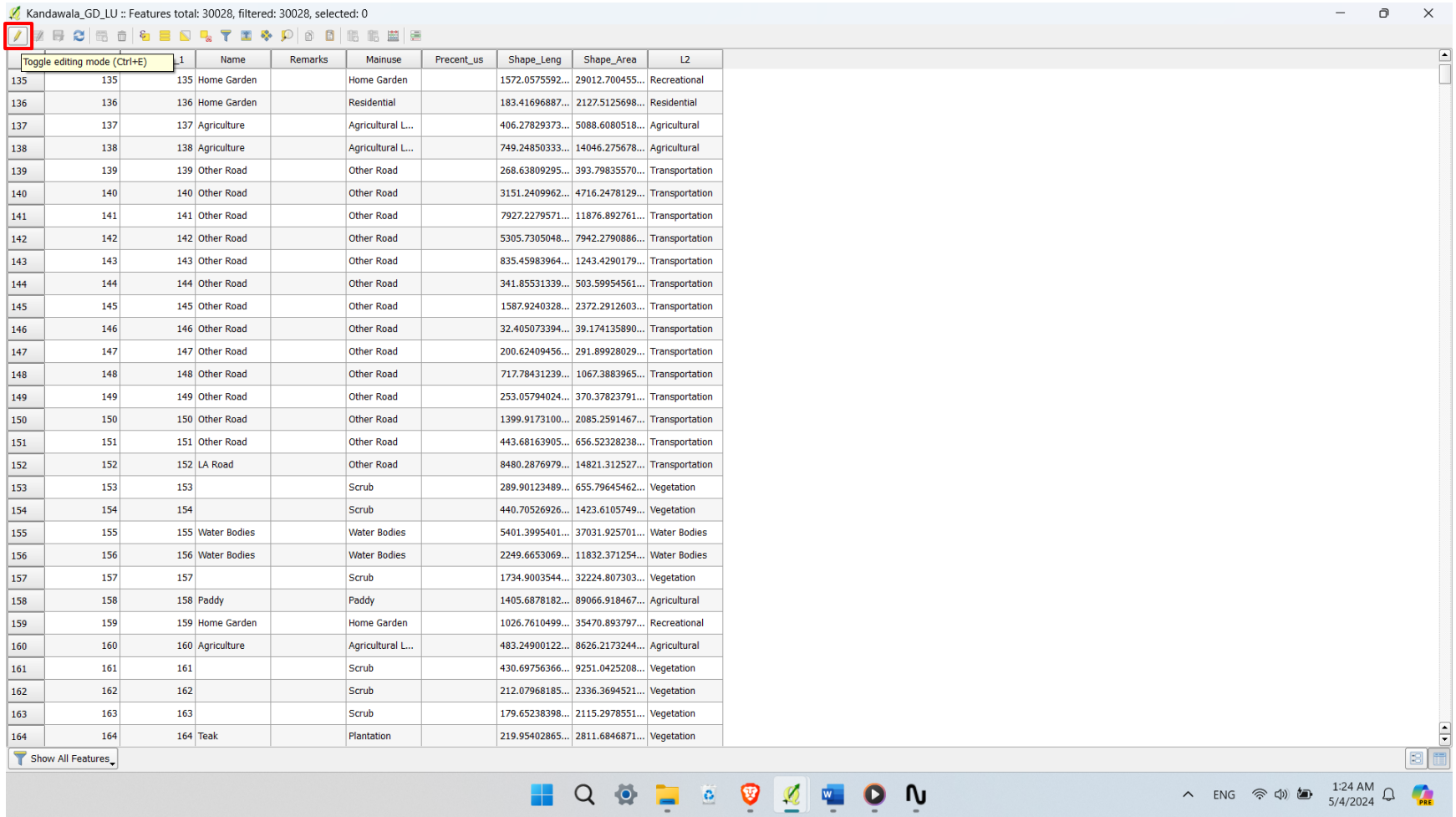


According to the previous step, all the unique related to “Mainuse” will be shown as follows.



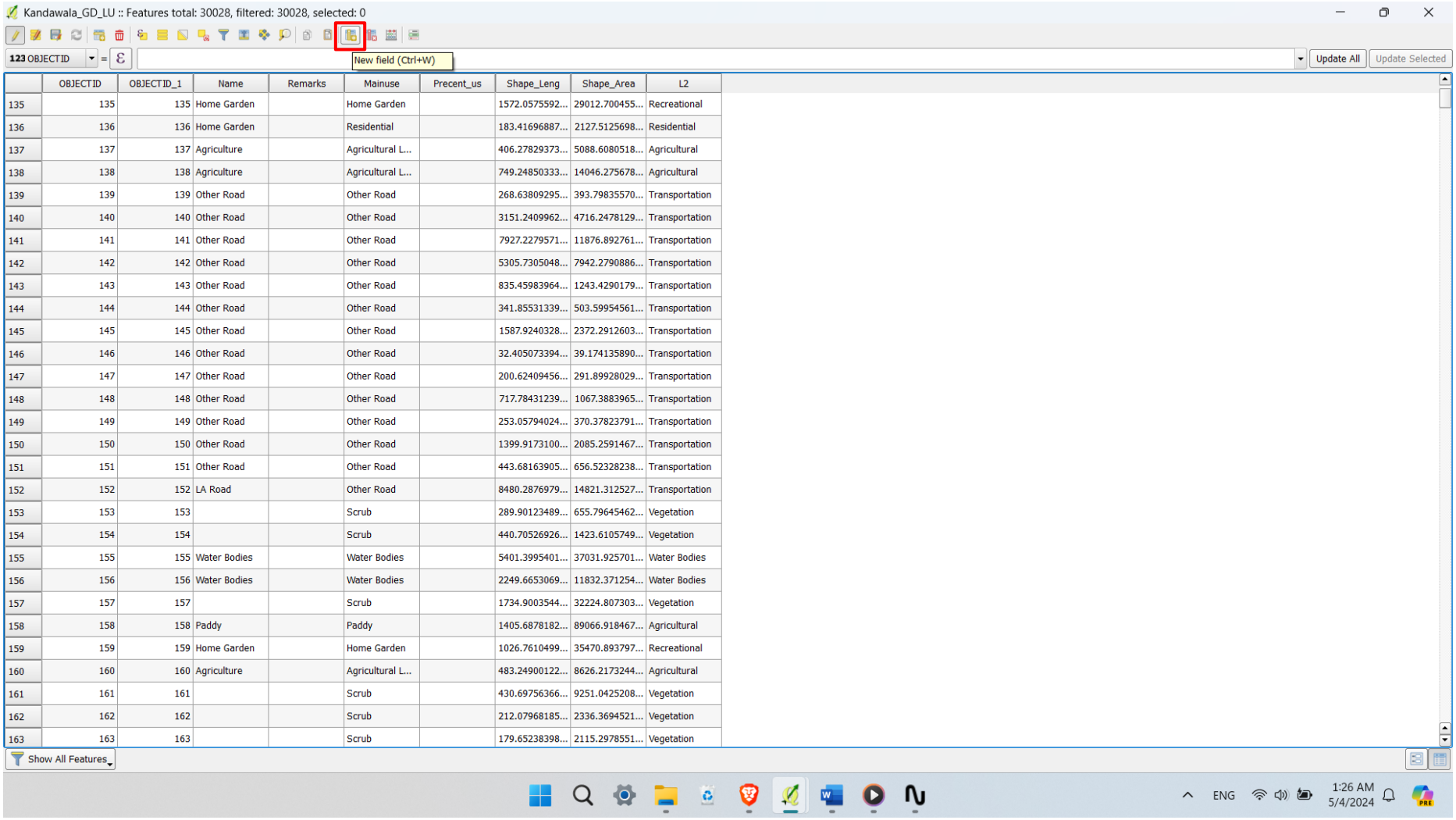
Now, we have to select land use categories under these 3 sensitivity classes, and we can give a value to each class and enter those values in the attribute table. According to these, we can use **1 for low sensitivity, 2 for medium sensitivity, and 3 for high sensitivity**.

- First, we should create a new field in the attribute table named "**Env_Sens**".
- Click on the pencil icon and turn on the "**Toggle editing mode**".



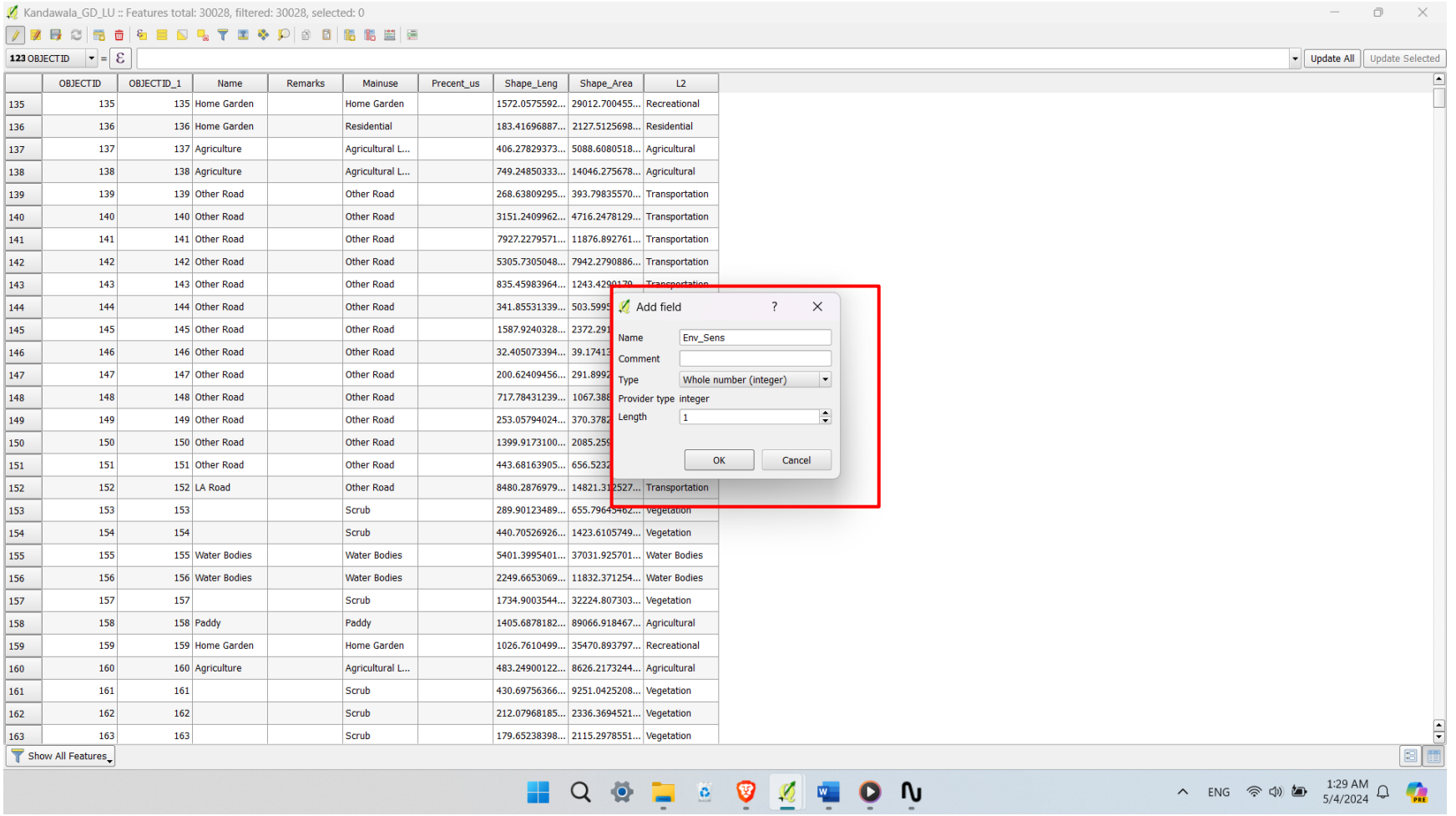
	_1		Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2
135	135	135	Home Garden		Home Garden		1572.0575592...	29012.700455...	Recreational
136	136	136	Home Garden		Residential		183.41696887...	2127.5125698...	Residential
137	137	137	Agriculture		Agricultural L...		406.27829373...	5088.6080518...	Agricultural
138	138	138	Agriculture		Agricultural L...		749.24850333...	14046.275678...	Agricultural
139	139	139	Other Road		Other Road		268.63809295...	393.79835570...	Transportation
140	140	140	Other Road		Other Road		3151.2409962...	4716.2478129...	Transportation
141	141	141	Other Road		Other Road		7927.2279571...	11876.892761...	Transportation
142	142	142	Other Road		Other Road		5305.7305048...	7942.2790886...	Transportation
143	143	143	Other Road		Other Road		835.45983964...	1243.4290179...	Transportation
144	144	144	Other Road		Other Road		341.85531339...	503.59954561...	Transportation
145	145	145	Other Road		Other Road		1587.9240328...	2372.2912603...	Transportation
146	146	146	Other Road		Other Road		32.405073394...	39.174135890...	Transportation
147	147	147	Other Road		Other Road		200.62409456...	291.89928029...	Transportation
148	148	148	Other Road		Other Road		717.78431239...	1067.3883965...	Transportation
149	149	149	Other Road		Other Road		253.05794024...	370.37823791...	Transportation
150	150	150	Other Road		Other Road		1399.9173100...	2085.2591467...	Transportation
151	151	151	Other Road		Other Road		443.68163905...	656.52328238...	Transportation
152	152	152	LA Road		Other Road		8480.2876979...	14821.312527...	Transportation
153	153	153			Scrub		289.90123489...	655.79645462...	Vegetation
154	154	154			Scrub		440.70526926...	1423.6105749...	Vegetation
155	155	155	Water Bodies		Water Bodies		5401.3995401...	37031.925701...	Water Bodies
156	156	156	Water Bodies		Water Bodies		2249.6653069...	11832.371254...	Water Bodies
157	157	157			Scrub		1734.9003544...	32224.807303...	Vegetation
158	158	158	Paddy		Paddy		1405.6878182...	89066.918467...	Agricultural
159	159	159	Home Garden		Home Garden		1026.7610499...	35470.893797...	Recreational
160	160	160	Agriculture		Agricultural L...		483.24900122...	8626.2173244...	Agricultural
161	161	161			Scrub		430.69756366...	9251.0425208...	Vegetation
162	162	162			Scrub		212.07968185...	2336.3694521...	Vegetation
163	163	163			Scrub		179.65238398...	2115.2978551...	Vegetation
164	164	164	Teak		Plantation		219.95402865...	2811.6846871...	Vegetation

Now the layer is in editable mode. Then, click on the icon for “**New field**” as follows.



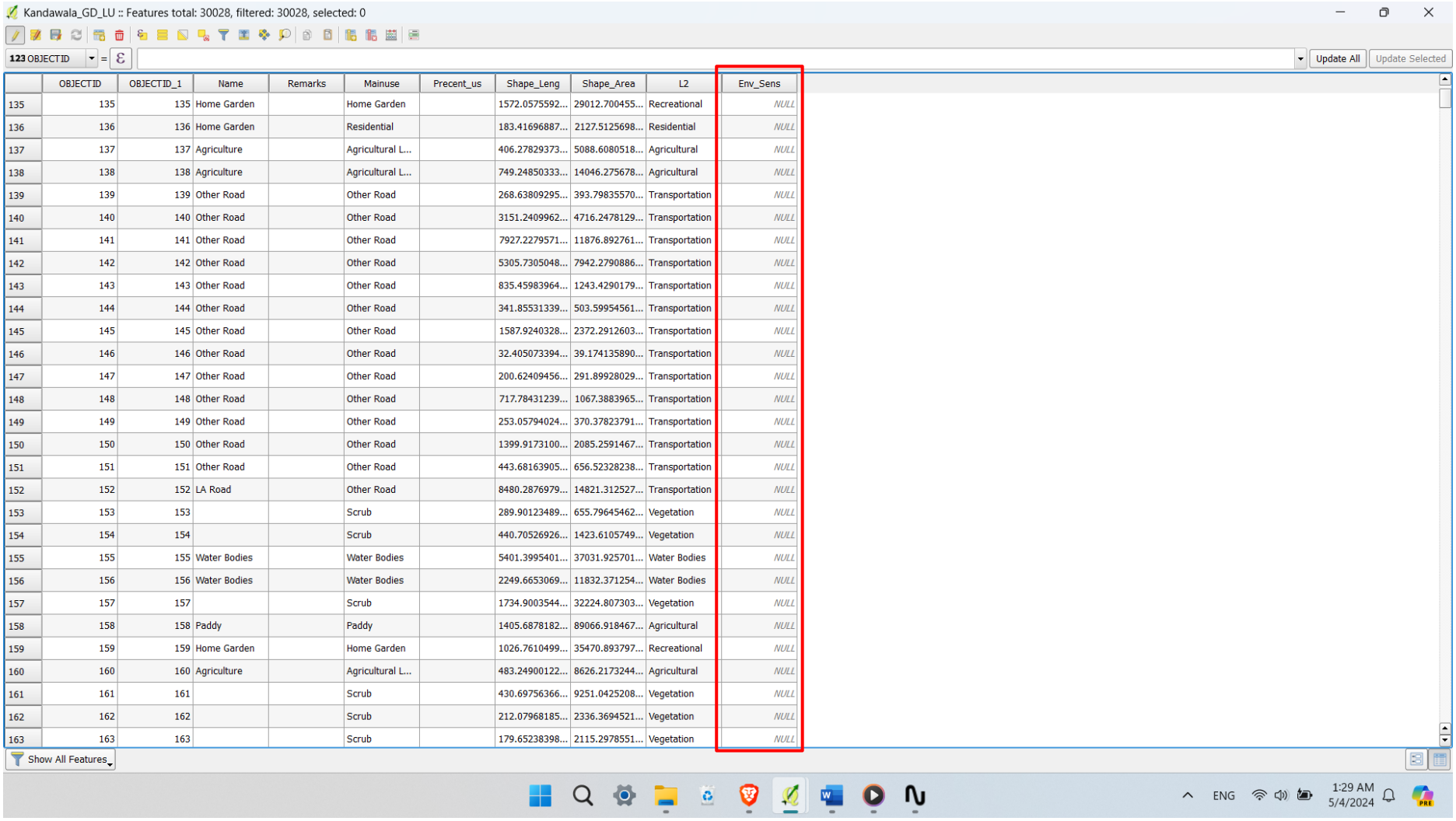
	OBJECTID	OBJECTID_1	Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2
135	135	135	Home Garden		Home Garden		1572.0575592...	29012.700455...	Recreational
136	136	136	Home Garden		Residential		183.41696887...	2127.5125698...	Residential
137	137	137	Agriculture		Agricultural L...		406.27829373...	5088.6080518...	Agricultural
138	138	138	Agriculture		Agricultural L...		749.24850333...	14046.275678...	Agricultural
139	139	139	Other Road		Other Road		268.63809295...	393.79835570...	Transportation
140	140	140	Other Road		Other Road		3151.2409962...	4716.2478129...	Transportation
141	141	141	Other Road		Other Road		7927.2279571...	11876.892761...	Transportation
142	142	142	Other Road		Other Road		5305.7305048...	7942.2790886...	Transportation
143	143	143	Other Road		Other Road		835.45983964...	1243.4290179...	Transportation
144	144	144	Other Road		Other Road		341.85531339...	503.59954561...	Transportation
145	145	145	Other Road		Other Road		1587.9240328...	2372.2912603...	Transportation
146	146	146	Other Road		Other Road		32.405073394...	39.174135890...	Transportation
147	147	147	Other Road		Other Road		200.62409456...	291.89928029...	Transportation
148	148	148	Other Road		Other Road		717.78431239...	1067.3883965...	Transportation
149	149	149	Other Road		Other Road		253.05794024...	370.37823791...	Transportation
150	150	150	Other Road		Other Road		1399.9173100...	2085.2591467...	Transportation
151	151	151	Other Road		Other Road		443.68163905...	656.52328238...	Transportation
152	152	152	LA Road		Other Road		8480.2876979...	14821.312527...	Transportation
153	153	153			Scrub		289.90123489...	655.79645462...	Vegetation
154	154	154			Scrub		440.70526926...	1423.6105749...	Vegetation
155	155	155	Water Bodies		Water Bodies		5401.3995401...	37031.925701...	Water Bodies
156	156	156	Water Bodies		Water Bodies		2249.6653069...	11832.371254...	Water Bodies
157	157	157			Scrub		1734.9003544...	32224.807303...	Vegetation
158	158	158	Paddy		Paddy		1405.6878182...	89066.918467...	Agricultural
159	159	159	Home Garden		Home Garden		1026.7610499...	35470.893797...	Recreational
160	160	160	Agriculture		Agricultural L...		483.24900122...	8626.2173244...	Agricultural
161	161	161			Scrub		430.69756366...	9251.0425208...	Vegetation
162	162	162			Scrub		212.07968185...	2336.3694521...	Vegetation
163	163	163			Scrub		179.65238398...	2115.2978551...	Vegetation

After clicking on the “New field” icon, the following window will open. Enter the Name as “Env_Sens” and keep the other settings default. We can keep the length of the integer as 1, because there are only 3 classes that we are going to use in this.



	OBJECTID	OBJECTID_1	Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2
135	135	135	Home Garden		Home Garden		1572.0575592...	29012.700455...	Recreational
136	136	136	Home Garden		Residential		183.41696887...	2127.5125698...	Residential
137	137	137	Agriculture		Agricultural L...		406.27829373...	5088.6080518...	Agricultural
138	138	138	Agriculture		Agricultural L...		749.24850333...	14046.275678...	Agricultural
139	139	139	Other Road		Other Road		268.63809295...	393.79835570...	Transportation
140	140	140	Other Road		Other Road		3151.2409962...	4716.2478129...	Transportation
141	141	141	Other Road		Other Road		7927.2279571...	11876.892761...	Transportation
142	142	142	Other Road		Other Road		5305.7305048...	7942.2790886...	Transportation
143	143	143	Other Road		Other Road		835.45983964...	1243.4290170...	Transportation
144	144	144	Other Road		Other Road		341.85531339...	503.5995...	
145	145	145	Other Road		Other Road		1587.9240328...	2372.291...	
146	146	146	Other Road		Other Road		32.405073394...	39.17413...	
147	147	147	Other Road		Other Road		200.62409456...	291.8992...	
148	148	148	Other Road		Other Road		717.78431239...	1067.388...	
149	149	149	Other Road		Other Road		253.05794024...	370.3782...	
150	150	150	Other Road		Other Road		1399.9173100...	2085.259...	
151	151	151	Other Road		Other Road		443.68163905...	656.5232...	
152	152	152	LA Road		Other Road		8480.2876979...	14821.312527...	Transportation
153	153	153			Scrub		289.90123489...	655.79643462...	Vegetation
154	154	154			Scrub		440.70526926...	1423.6105749...	Vegetation
155	155	155	Water Bodies		Water Bodies		5401.3995401...	37031.925701...	Water Bodies
156	156	156	Water Bodies		Water Bodies		2249.6653069...	11832.371254...	Water Bodies
157	157	157			Scrub		1734.9003544...	32224.807303...	Vegetation
158	158	158	Paddy		Paddy		1405.6878182...	89066.918467...	Agricultural
159	159	159	Home Garden		Home Garden		1026.7610499...	35470.893797...	Recreational
160	160	160	Agriculture		Agricultural L...		483.24900122...	8626.2173244...	Agricultural
161	161	161			Scrub		430.69756366...	9251.0425208...	Vegetation
162	162	162			Scrub		212.07968185...	2336.3694521...	Vegetation
163	163	163			Scrub		179.65238398...	2115.2978551...	Vegetation

Then the newly added field will be shown as follows.



	OBJECTID	OBJECTID_1	Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2	Env_Sens
135	135	135	Home Garden		Home Garden		1572.0575592...	29012.700455...	Recreational	NULL
136	136	136	Home Garden		Residential		183.41696887...	2127.5125698...	Residential	NULL
137	137	137	Agriculture		Agricultural L...		406.27829373...	5088.6080518...	Agricultural	NULL
138	138	138	Agriculture		Agricultural L...		749.24850333...	14046.275678...	Agricultural	NULL
139	139	139	Other Road		Other Road		268.63809295...	393.79835570...	Transportation	NULL
140	140	140	Other Road		Other Road		3151.2409962...	4716.2478129...	Transportation	NULL
141	141	141	Other Road		Other Road		7927.2279571...	11876.892761...	Transportation	NULL
142	142	142	Other Road		Other Road		5305.7305048...	7942.2790886...	Transportation	NULL
143	143	143	Other Road		Other Road		835.45983964...	1243.4290179...	Transportation	NULL
144	144	144	Other Road		Other Road		341.85531339...	503.59954561...	Transportation	NULL
145	145	145	Other Road		Other Road		1587.9240328...	2372.2912603...	Transportation	NULL
146	146	146	Other Road		Other Road		32.405073394...	39.174135890...	Transportation	NULL
147	147	147	Other Road		Other Road		200.62409456...	291.89928029...	Transportation	NULL
148	148	148	Other Road		Other Road		717.78431239...	1067.3883965...	Transportation	NULL
149	149	149	Other Road		Other Road		253.05794024...	370.37823791...	Transportation	NULL
150	150	150	Other Road		Other Road		1399.9173100...	2085.2591467...	Transportation	NULL
151	151	151	Other Road		Other Road		443.68163905...	656.52328238...	Transportation	NULL
152	152	152	LA Road		Other Road		8480.2876979...	14821.312527...	Transportation	NULL
153	153	153			Scrub		289.90123489...	655.79645462...	Vegetation	NULL
154	154	154			Scrub		440.70526926...	1423.6105749...	Vegetation	NULL
155	155	155	Water Bodies		Water Bodies		5401.3995401...	37031.925701...	Water Bodies	NULL
156	156	156	Water Bodies		Water Bodies		2249.6653069...	11832.371254...	Water Bodies	NULL
157	157	157			Scrub		1734.9003544...	32224.807303...	Vegetation	NULL
158	158	158	Paddy		Paddy		1405.6878182...	89066.918467...	Agricultural	NULL
159	159	159	Home Garden		Home Garden		1026.7610499...	35470.893797...	Recreational	NULL
160	160	160	Agriculture		Agricultural L...		483.24900122...	8626.2173244...	Agricultural	NULL
161	161	161			Scrub		430.69756366...	9251.0425208...	Vegetation	NULL
162	162	162			Scrub		212.07968185...	2336.3694521...	Vegetation	NULL
163	163	163			Scrub		179.65238398...	2115.2978551...	Vegetation	NULL

Now, we have to add the values into this new field. For that, we should filter each sensitivity class by land uses from the attribute table.

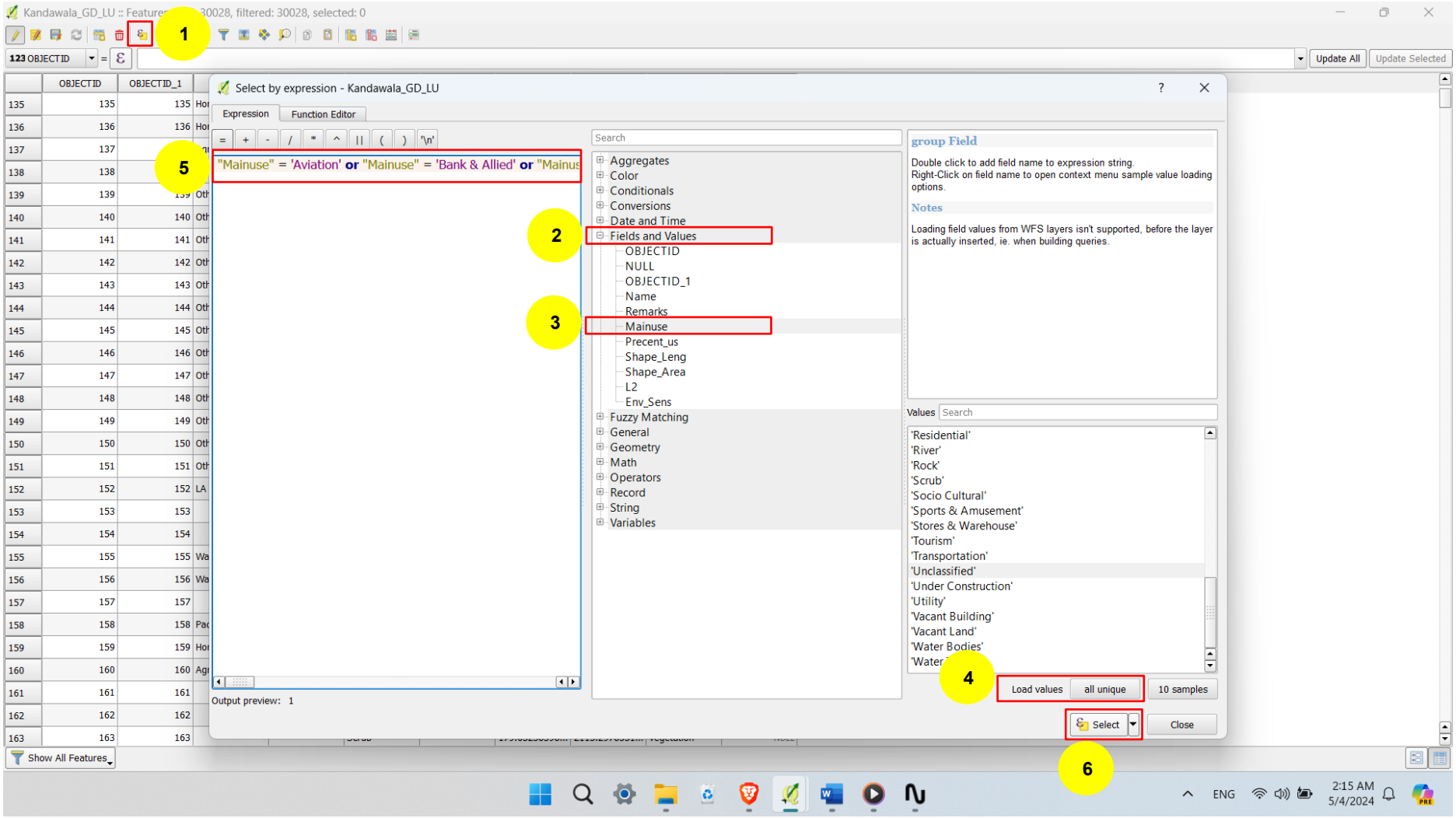
1. Open the "**Select by the expression**" as before mentioned way.
2. Expand the "**Fields and Values**".
3. Double-click on "**Mainuse**".
4. Click on "**all unique**". All the uniques under the "Mainuse" will be shown as follows.
5. Then, you have to enter the following expression on the expression tab. For that, double-click on "**Mainuse**", type "**=**", and double-click on the relevant land use category according to the sensitivity classes.

According to the above steps, first, select the land uses under the low sensitivity class. Once done entering a land use using this [**"Mainuse" = 'Aviation'**], type "**or**" and follow the same steps to add other land use categories into the expression. The "or" operator is used here to create a logical condition that selects features based on multiple criteria.

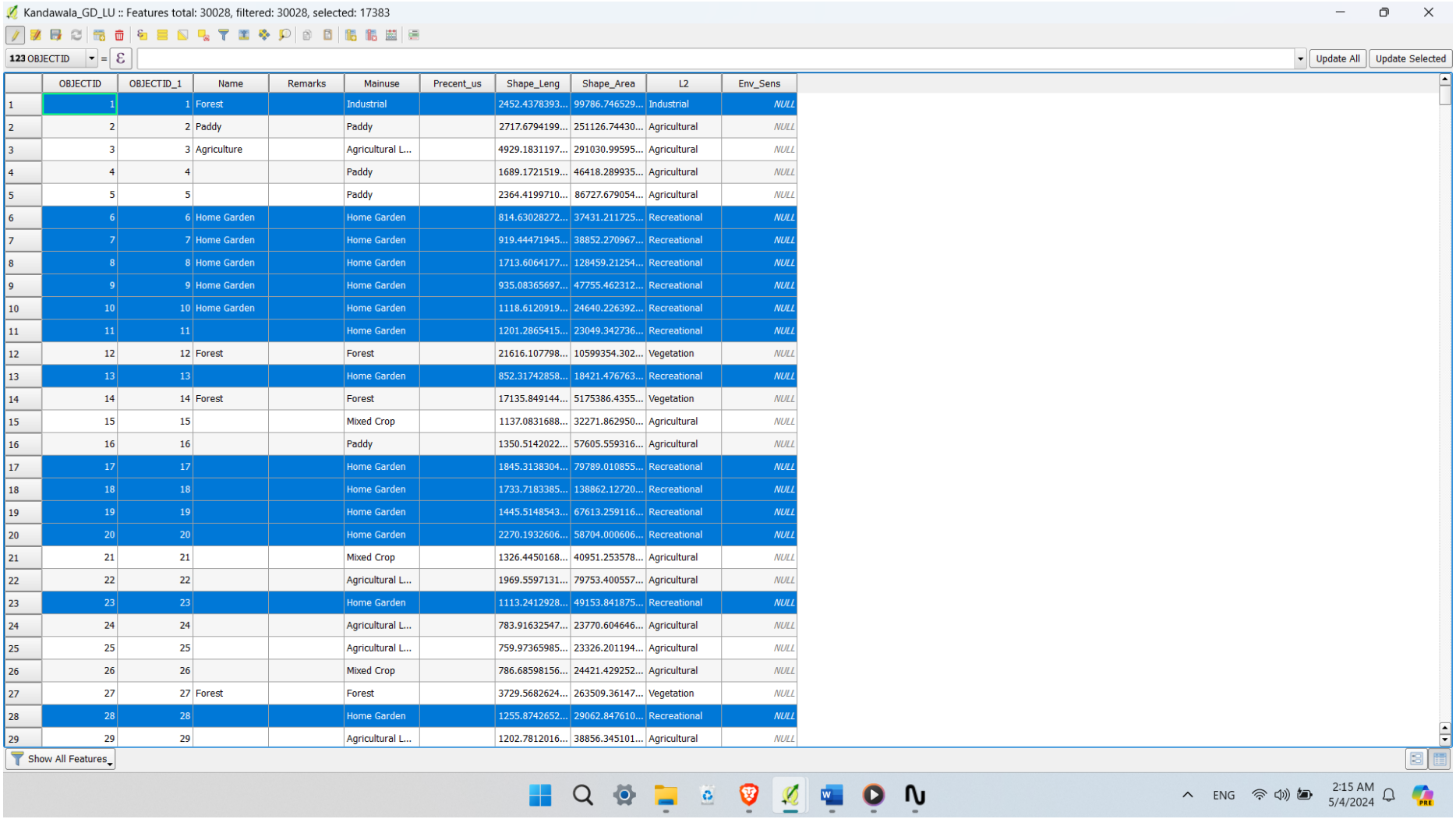
- So, add each land use continuously in this way,

  "Mainuse" = 'Aviation' or "Mainuse" = 'Bank & Allied' or "Mainuse" = 'Commercial' or "Mainuse" = 'Educational'

After entering all land use categories into the expression using the above way, click on "**Select**".

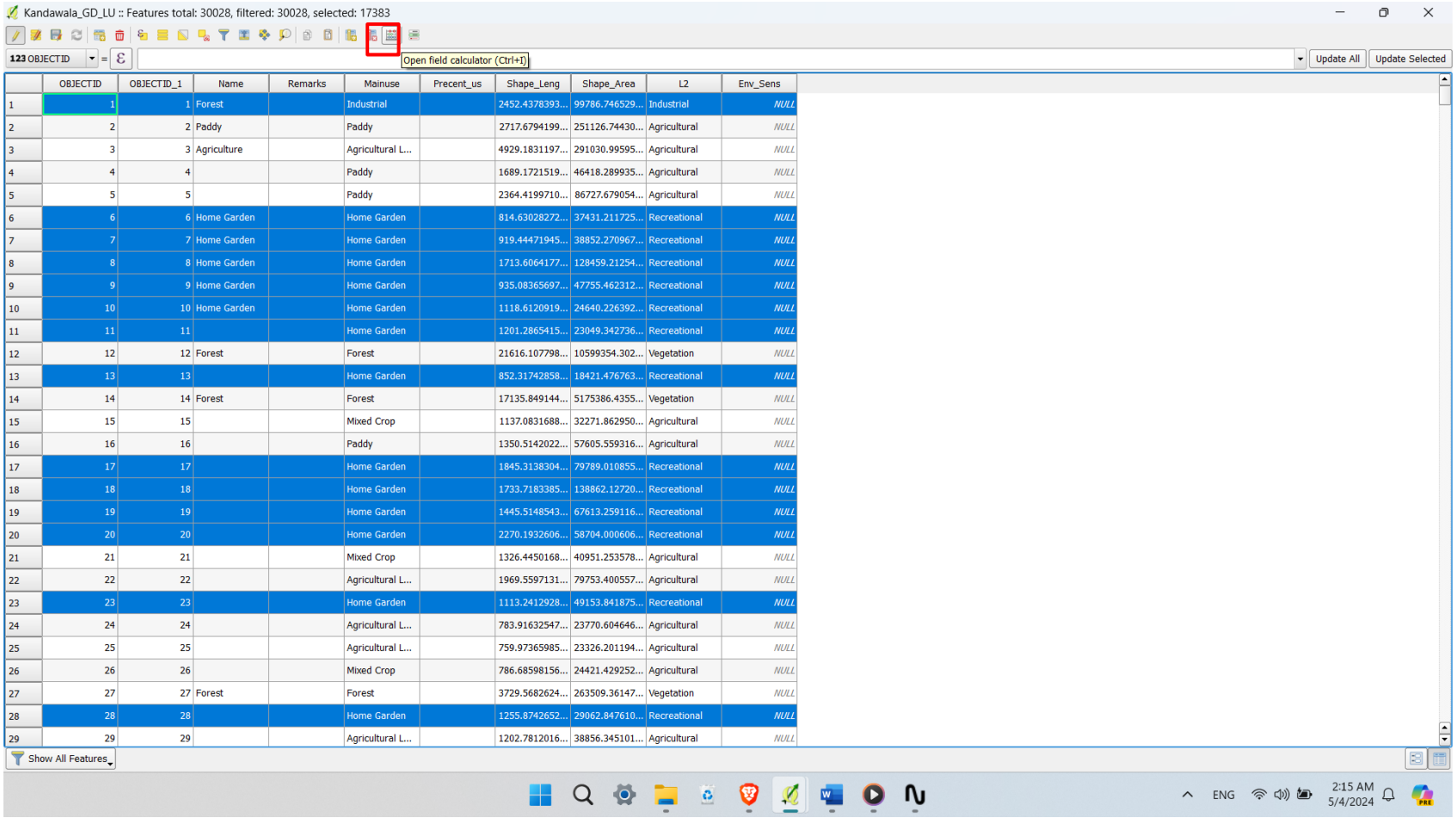

1
2
3
4
5
6
Select by expression - Kandawala_GD_LU
Expression
Function Editor
"Mainuse" = 'Aviation' or "Mainuse" = 'Bank & Allied' or "Mainus
Search
Aggregates
Color
Conditionals
Conversions
Date and Time
Fields and Values
OBJECTID
NULL
OBJECTID_1
Name
Remarks
Mainuse
Precent_us
Shape_Leng
Shape_Area
L2
Env_Sens
Fuzzy Matching
General
Geometry
Math
Operators
Record
String
Variables
group Field
Double click to add field name to expression string.
Right-Click on field name to open context menu sample value loading options.
Notes
Loading field values from WFS layers isn't supported, before the layer is actually inserted, ie. when building queries.
Values
Search
'Residential'
'River'
'Rock'
'Scrub'
'Socio Cultural'
'Sports & Amusement'
'Stores & Warehouse'
'Tourism'
'Transportation'
'Unclassified'
'Under Construction'
'Utility'
'Vacant Building'
'Vacant Land'
'Water Bodies'
Load values
all unique
10 samples
Output preview: 1
Select
Close
Update All
Update Selected
Show All Features

The selected data will be shown as follows.



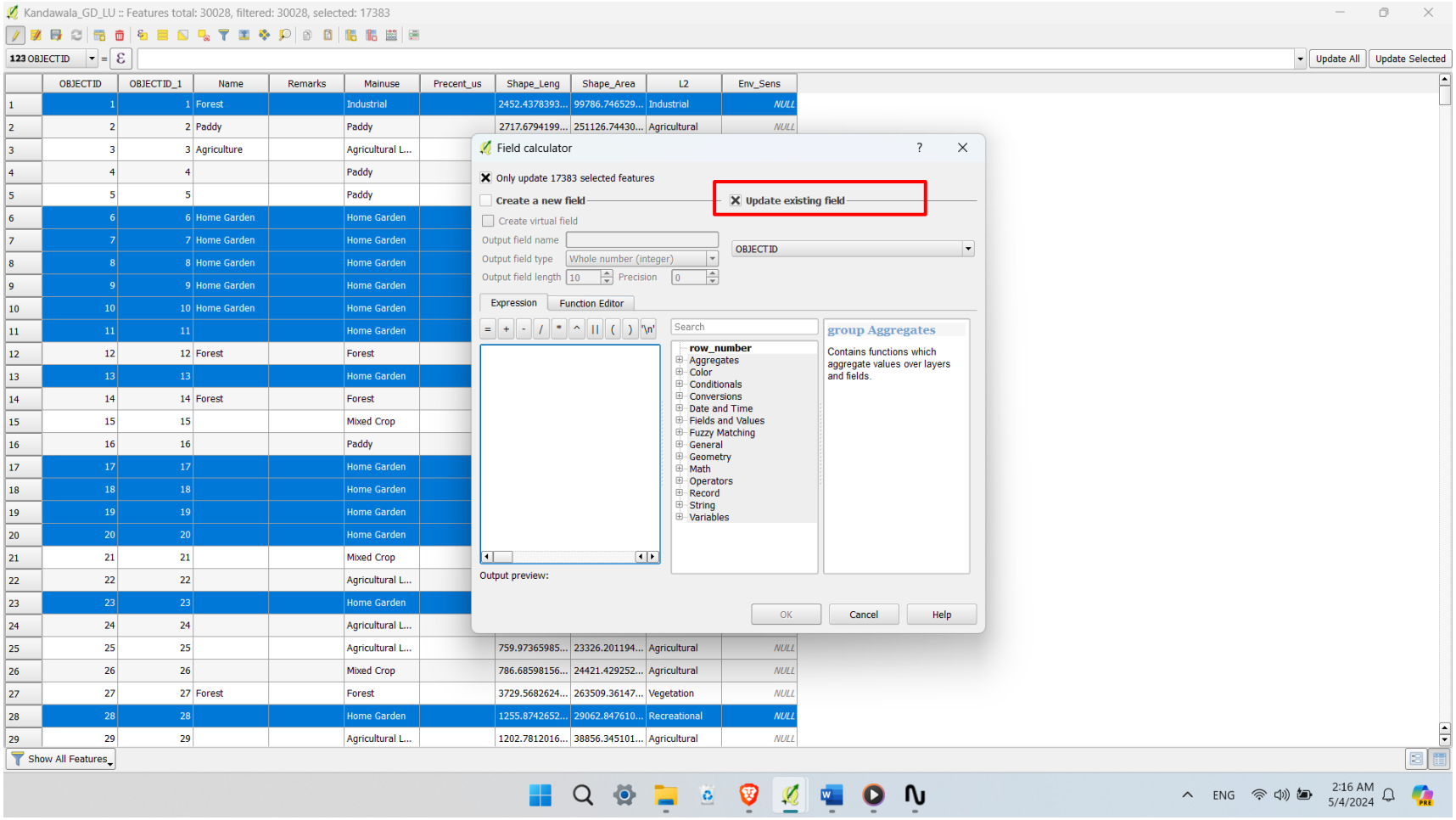
	OBJECTID	OBJECTID_1	Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2	Env_Sens
1	1	1	Forest		Industrial		2452.4378393...	99786.746529...	Industrial	NULL
2	2	2	Paddy		Paddy		2717.6794199...	251126.74430...	Agricultural	NULL
3	3	3	Agriculture		Agricultural L...		4929.1831197...	291030.99595...	Agricultural	NULL
4	4	4			Paddy		1689.1721519...	46418.289935...	Agricultural	NULL
5	5	5			Paddy		2364.4199710...	86727.679054...	Agricultural	NULL
6	6	6	Home Garden		Home Garden		814.63028272...	37431.211725...	Recreational	NULL
7	7	7	Home Garden		Home Garden		919.44471945...	38852.270967...	Recreational	NULL
8	8	8	Home Garden		Home Garden		1713.6064177...	128459.21254...	Recreational	NULL
9	9	9	Home Garden		Home Garden		935.08365697...	47755.462312...	Recreational	NULL
10	10	10	Home Garden		Home Garden		1118.6120919...	24640.226392...	Recreational	NULL
11	11	11			Home Garden		1201.2865415...	23049.342736...	Recreational	NULL
12	12	12	Forest		Forest		21616.107798...	10599354.302...	Vegetation	NULL
13	13	13			Home Garden		852.31742858...	18421.476763...	Recreational	NULL
14	14	14	Forest		Forest		17135.849144...	5175386.4355...	Vegetation	NULL
15	15	15			Mixed Crop		1137.0831688...	32271.862950...	Agricultural	NULL
16	16	16			Paddy		1350.5142022...	57605.559316...	Agricultural	NULL
17	17	17			Home Garden		1845.3138304...	79789.010855...	Recreational	NULL
18	18	18			Home Garden		1733.7183385...	138862.12720...	Recreational	NULL
19	19	19			Home Garden		1445.5148543...	67613.259116...	Recreational	NULL
20	20	20			Home Garden		2270.1932606...	58704.000606...	Recreational	NULL
21	21	21			Mixed Crop		1326.4450168...	40951.253578...	Agricultural	NULL
22	22	22			Agricultural L...		1969.5597131...	79753.400557...	Agricultural	NULL
23	23	23			Home Garden		1113.2412928...	49153.841875...	Recreational	NULL
24	24	24			Agricultural L...		783.91632547...	23770.604646...	Agricultural	NULL
25	25	25			Agricultural L...		759.97365985...	23326.201194...	Agricultural	NULL
26	26	26			Mixed Crop		786.68598156...	24421.429252...	Agricultural	NULL
27	27	27	Forest		Forest		3729.5682624...	263509.36147...	Vegetation	NULL
28	28	28			Home Garden		1255.8742652...	29062.847610...	Recreational	NULL
29	29	29			Agricultural L...		1202.7812016...	38856.345101...	Agricultural	NULL

In the next step, we have to add the value for the “Env_Sens” column. According to the above steps, we selected here the **low-sensitive land use categories** and we assigned the value “**1**” for this sensitive class. For that, click on the icon for “**Open field calculator**”.

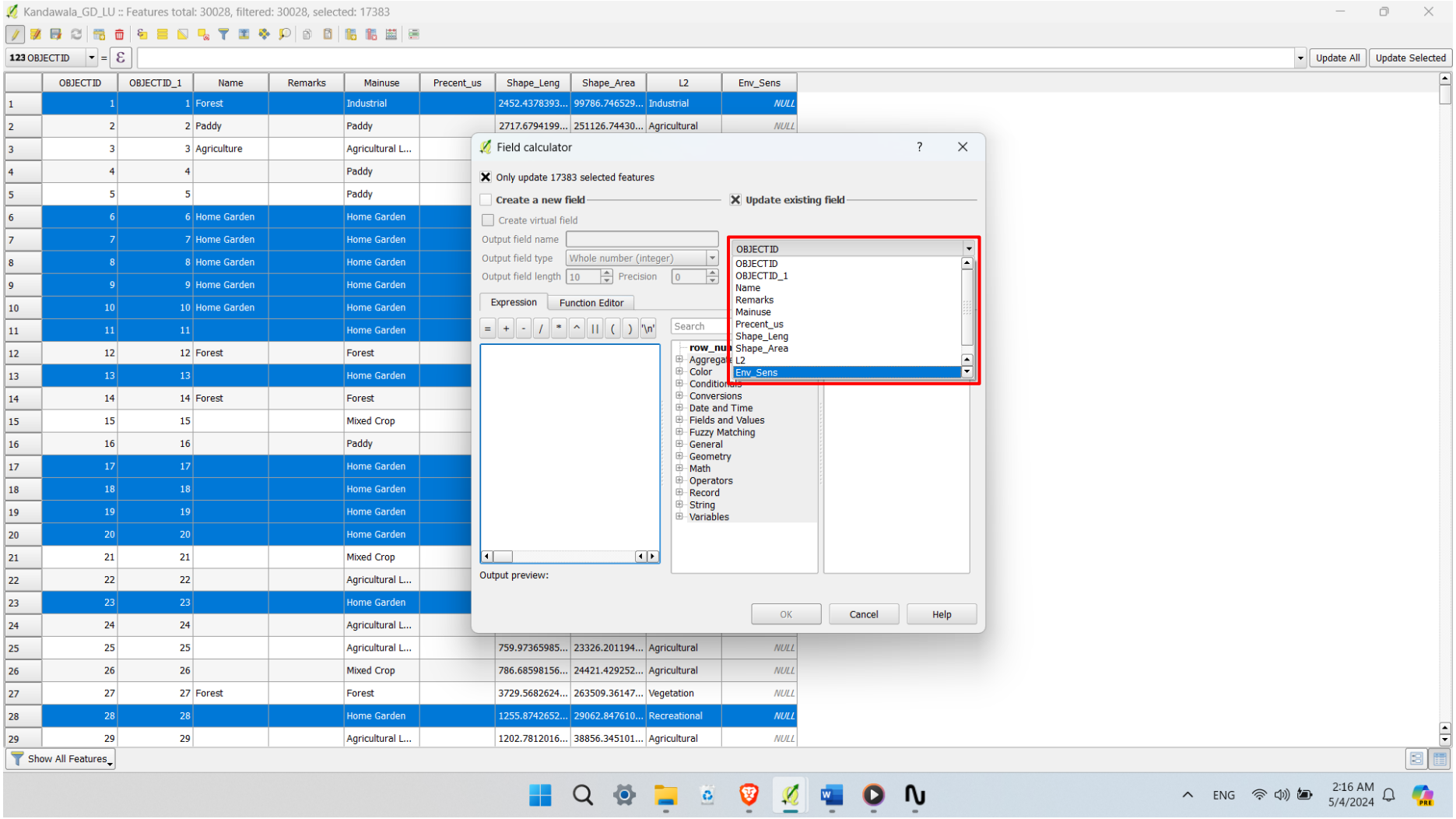


	OBJECTID	OBJECTID_1	Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2	Env_Sens
1	1	1	Forest		Industrial		2452.4378393...	99786.746529...	Industrial	NULL
2	2	2	Paddy		Paddy		2717.6794199...	251126.74430...	Agricultural	NULL
3	3	3	Agriculture		Agricultural L...		4929.1831197...	291030.99595...	Agricultural	NULL
4	4	4			Paddy		1689.1721519...	46418.289935...	Agricultural	NULL
5	5	5			Paddy		2364.4199710...	86727.679054...	Agricultural	NULL
6	6	6	Home Garden		Home Garden		814.63028272...	37431.211725...	Recreational	NULL
7	7	7	Home Garden		Home Garden		919.44471945...	38852.270967...	Recreational	NULL
8	8	8	Home Garden		Home Garden		1713.6064177...	128459.21254...	Recreational	NULL
9	9	9	Home Garden		Home Garden		935.08365697...	47755.462312...	Recreational	NULL
10	10	10	Home Garden		Home Garden		1118.6120919...	24640.226392...	Recreational	NULL
11	11	11			Home Garden		1201.2865415...	23049.342736...	Recreational	NULL
12	12	12	Forest		Forest		21616.107798...	10599354.302...	Vegetation	NULL
13	13	13			Home Garden		852.31742858...	18421.476763...	Recreational	NULL
14	14	14	Forest		Forest		17135.849144...	5175386.4355...	Vegetation	NULL
15	15	15			Mixed Crop		1137.0831688...	32271.862950...	Agricultural	NULL
16	16	16			Paddy		1350.5142022...	57605.559316...	Agricultural	NULL
17	17	17			Home Garden		1845.3138304...	79789.010855...	Recreational	NULL
18	18	18			Home Garden		1733.7183385...	138862.12720...	Recreational	NULL
19	19	19			Home Garden		1445.5148543...	67613.259116...	Recreational	NULL
20	20	20			Home Garden		2270.1932606...	58704.000606...	Recreational	NULL
21	21	21			Mixed Crop		1326.4450168...	40951.253578...	Agricultural	NULL
22	22	22			Agricultural L...		1969.5597131...	79753.400557...	Agricultural	NULL
23	23	23			Home Garden		1113.2412928...	49153.841875...	Recreational	NULL
24	24	24			Agricultural L...		783.91632547...	23770.604646...	Agricultural	NULL
25	25	25			Agricultural L...		759.97365985...	23326.201194...	Agricultural	NULL
26	26	26			Mixed Crop		786.68598156...	24421.429252...	Agricultural	NULL
27	27	27	Forest		Forest		3729.5682624...	263509.36147...	Vegetation	NULL
28	28	28			Home Garden		1255.8742652...	29062.847610...	Recreational	NULL
29	29	29			Agricultural L...		1202.7812016...	38856.345101...	Agricultural	NULL

The field calculator will open. Click on the “**Update existing field**” and make sure to display the “×” mark on that. Through this, an existing field in the attribute table is updated.



Now, we have to select the existing field that we want to update. For that, click on “**OBJECTID**” and expand it to the following fields. Then select “**Env_Sens**”.

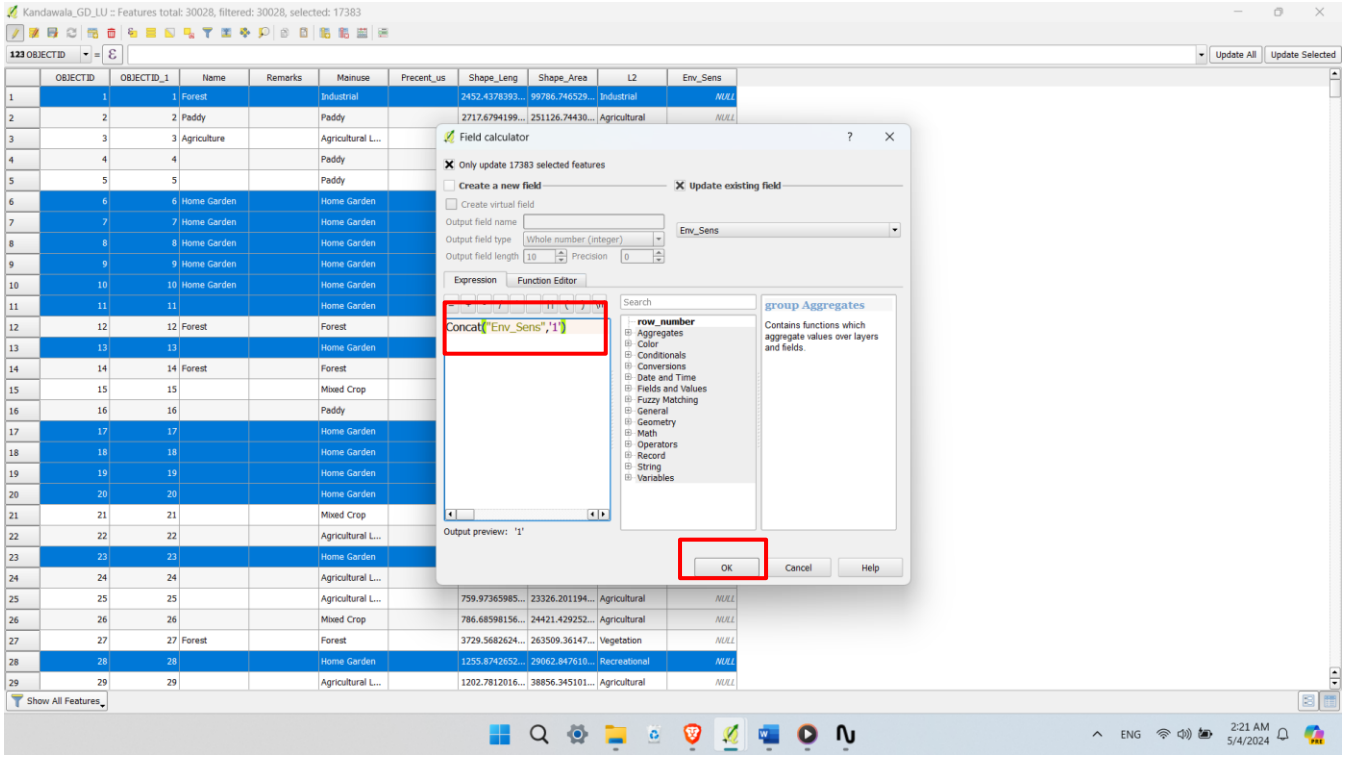


After selecting the field, you can use the following expression to add “**1**” to the selected field at once. Then the sensitivity of all the low-sensitive land use categories we selected above will be updated as "**1**" on the attribute table.

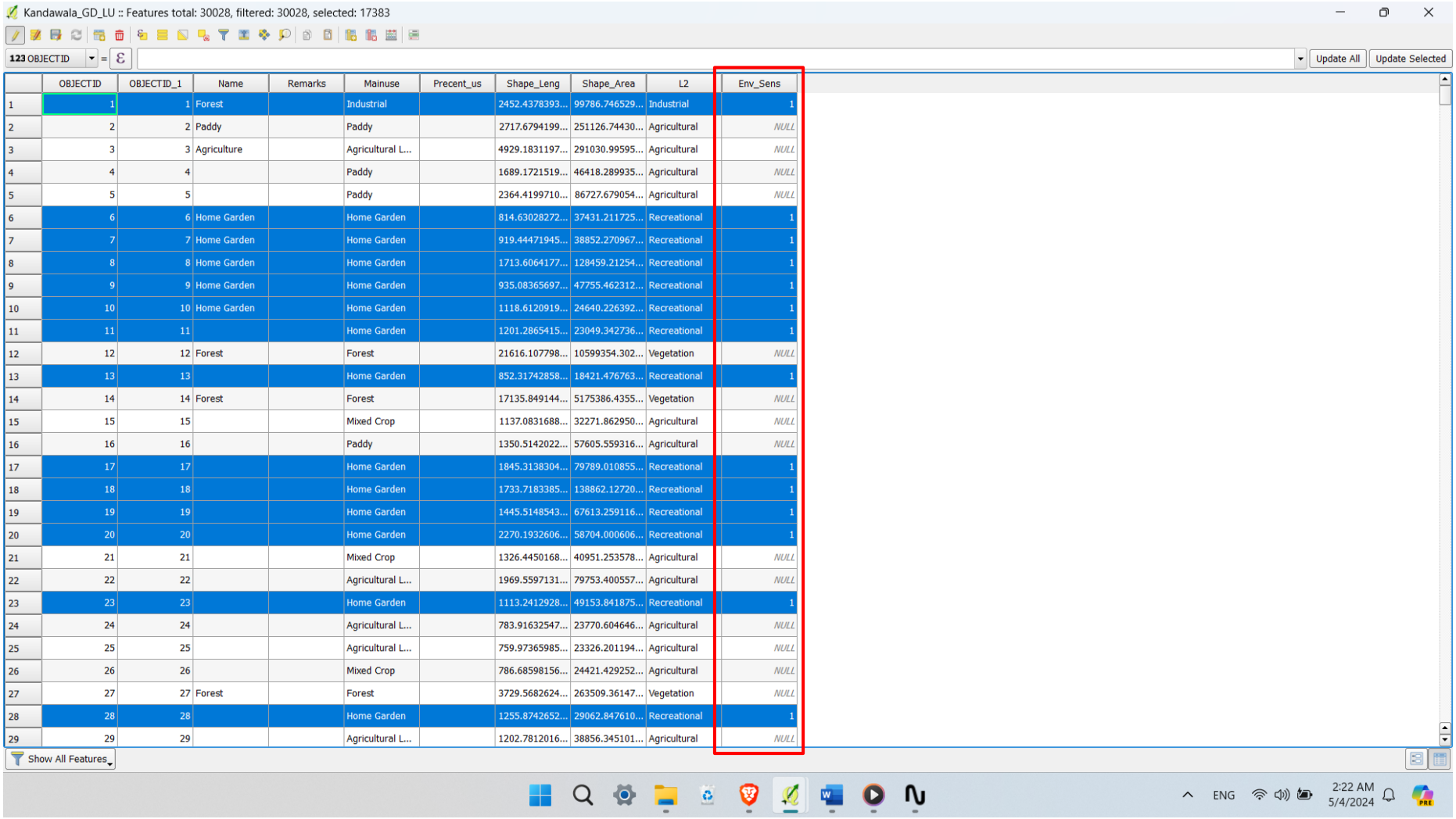
- Once done entering this expression, you can click on “**OK**” to proceed. This expression contains,

Concat (“Name of the existing field”, ‘The value’)

- You should correctly type this expression using single commas and double commas. If you do not enter this correctly, you will have an error message.

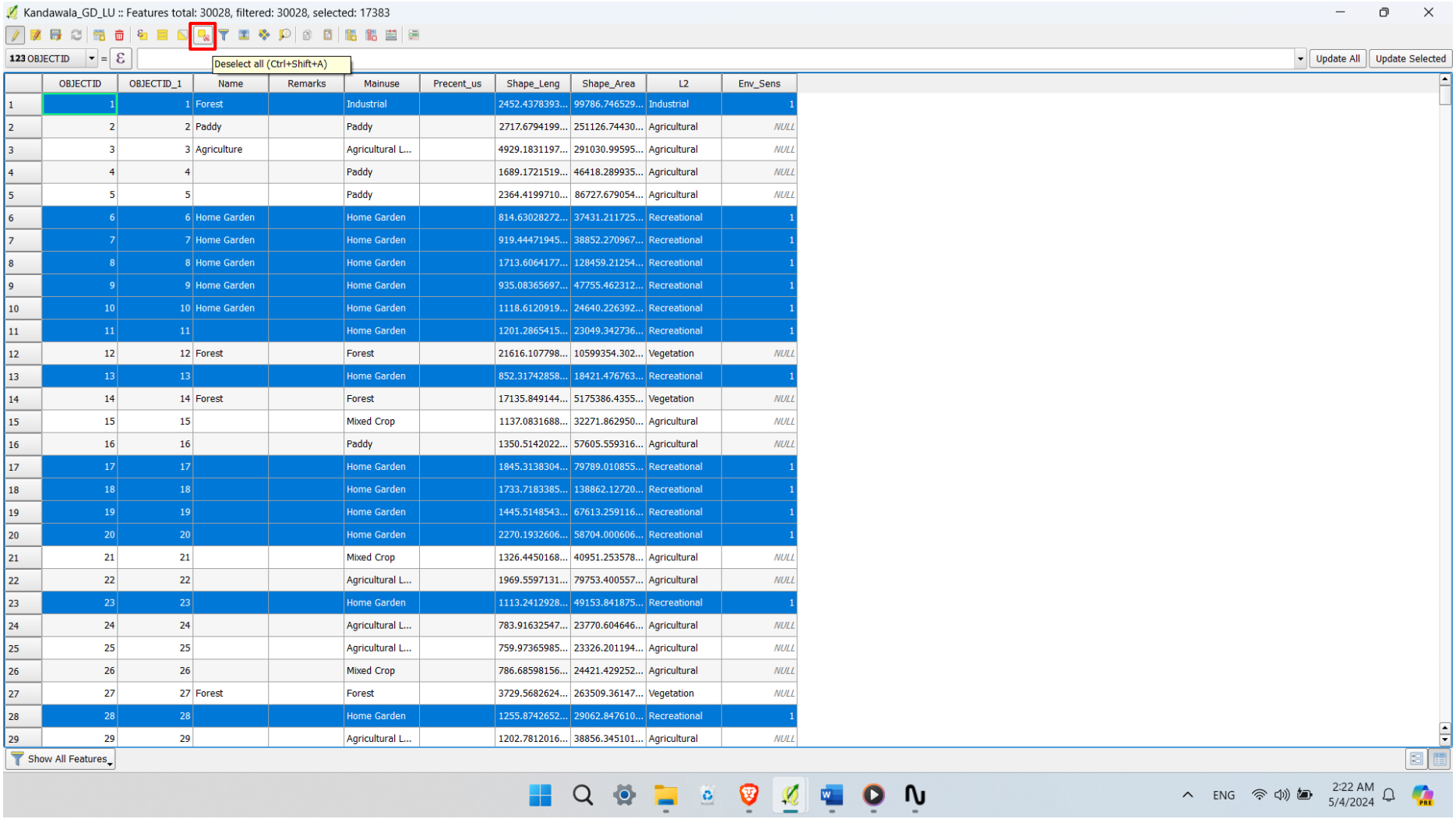


Now, the values are added to the attribute table.



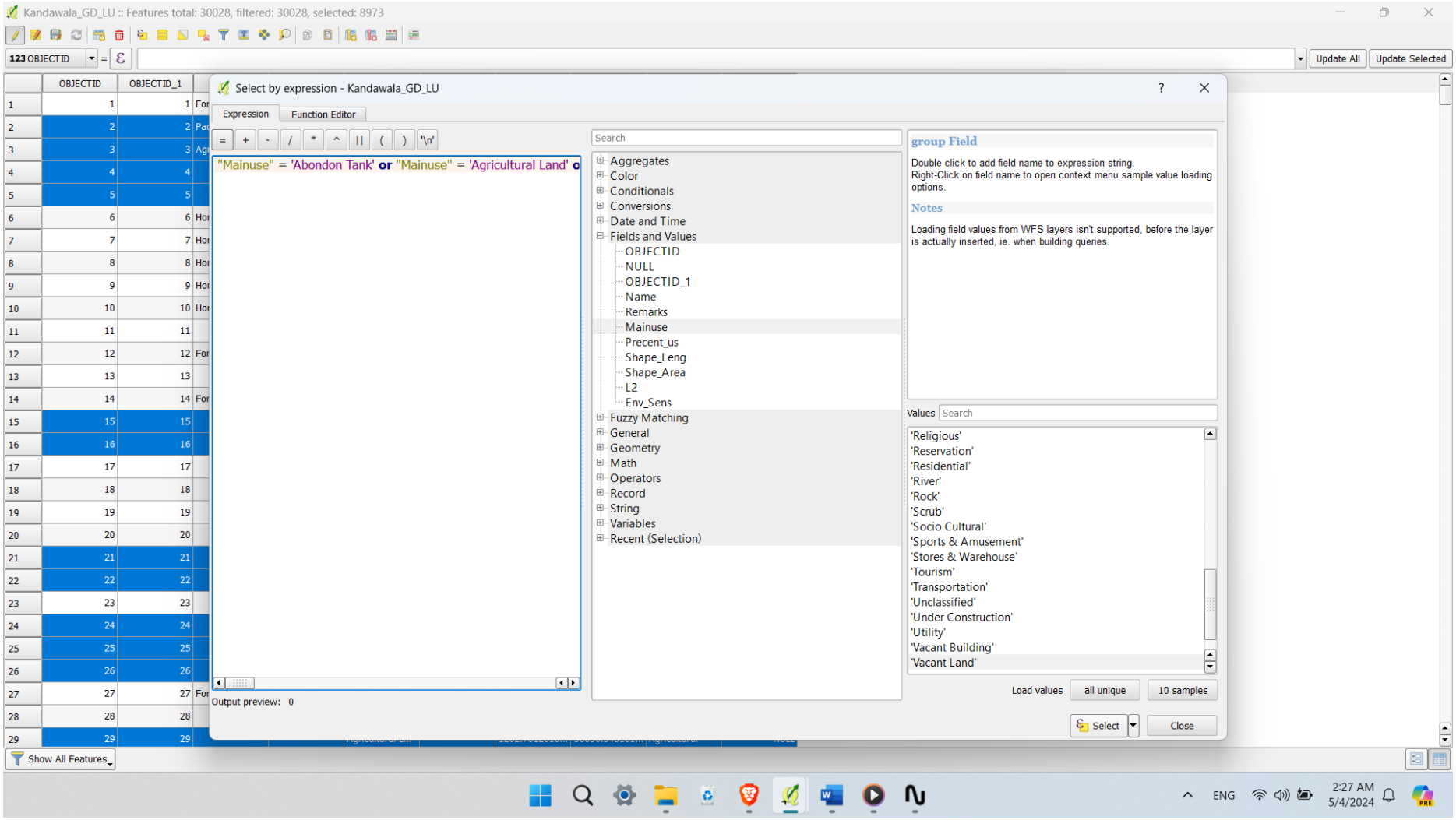
	OBJECTID	OBJECTID_1	Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2	Env_Sens
1	1	1	Forest		Industrial		2452.4378393...	99786.746529...	Industrial	1
2	2	2	Paddy		Paddy		2717.6794199...	251126.74430...	Agricultural	NULL
3	3	3	Agriculture		Agricultural L...		4929.1831197...	291030.99595...	Agricultural	NULL
4	4	4			Paddy		1689.1721519...	46418.289935...	Agricultural	NULL
5	5	5			Paddy		2364.4199710...	86727.679054...	Agricultural	NULL
6	6	6	Home Garden		Home Garden		814.63028272...	37431.211725...	Recreational	1
7	7	7	Home Garden		Home Garden		919.44471945...	38852.270967...	Recreational	1
8	8	8	Home Garden		Home Garden		1713.6064177...	128459.21254...	Recreational	1
9	9	9	Home Garden		Home Garden		935.08365697...	47755.462312...	Recreational	1
10	10	10	Home Garden		Home Garden		1118.6120919...	24640.226392...	Recreational	1
11	11	11			Home Garden		1201.2865415...	23049.342736...	Recreational	1
12	12	12	Forest		Forest		21616.107798...	10599354.302...	Vegetation	NULL
13	13	13			Home Garden		852.31742858...	18421.476763...	Recreational	1
14	14	14	Forest		Forest		17135.849144...	5175386.4355...	Vegetation	NULL
15	15	15			Mixed Crop		1137.0831688...	32271.862950...	Agricultural	NULL
16	16	16			Paddy		1350.5142022...	57605.559316...	Agricultural	NULL
17	17	17			Home Garden		1845.3138304...	79789.010855...	Recreational	1
18	18	18			Home Garden		1733.7183385...	138862.12720...	Recreational	1
19	19	19			Home Garden		1445.5148543...	67613.259116...	Recreational	1
20	20	20			Home Garden		2270.1932606...	58704.000606...	Recreational	1
21	21	21			Mixed Crop		1326.4450168...	40951.253578...	Agricultural	NULL
22	22	22			Agricultural L...		1969.5597131...	79753.400557...	Agricultural	NULL
23	23	23			Home Garden		1113.2412928...	49153.841875...	Recreational	1
24	24	24			Agricultural L...		783.91632547...	23770.604646...	Agricultural	NULL
25	25	25			Agricultural L...		759.97365985...	23326.201194...	Agricultural	NULL
26	26	26			Mixed Crop		786.68598156...	24421.429252...	Agricultural	NULL
27	27	27	Forest		Forest		3729.5682624...	263509.36147...	Vegetation	NULL
28	28	28			Home Garden		1255.8742652...	29062.847610...	Recreational	1
29	29	29			Agricultural L...		1202.7812016...	38856.345101...	Agricultural	NULL

You can deselect these all features using the below tool.

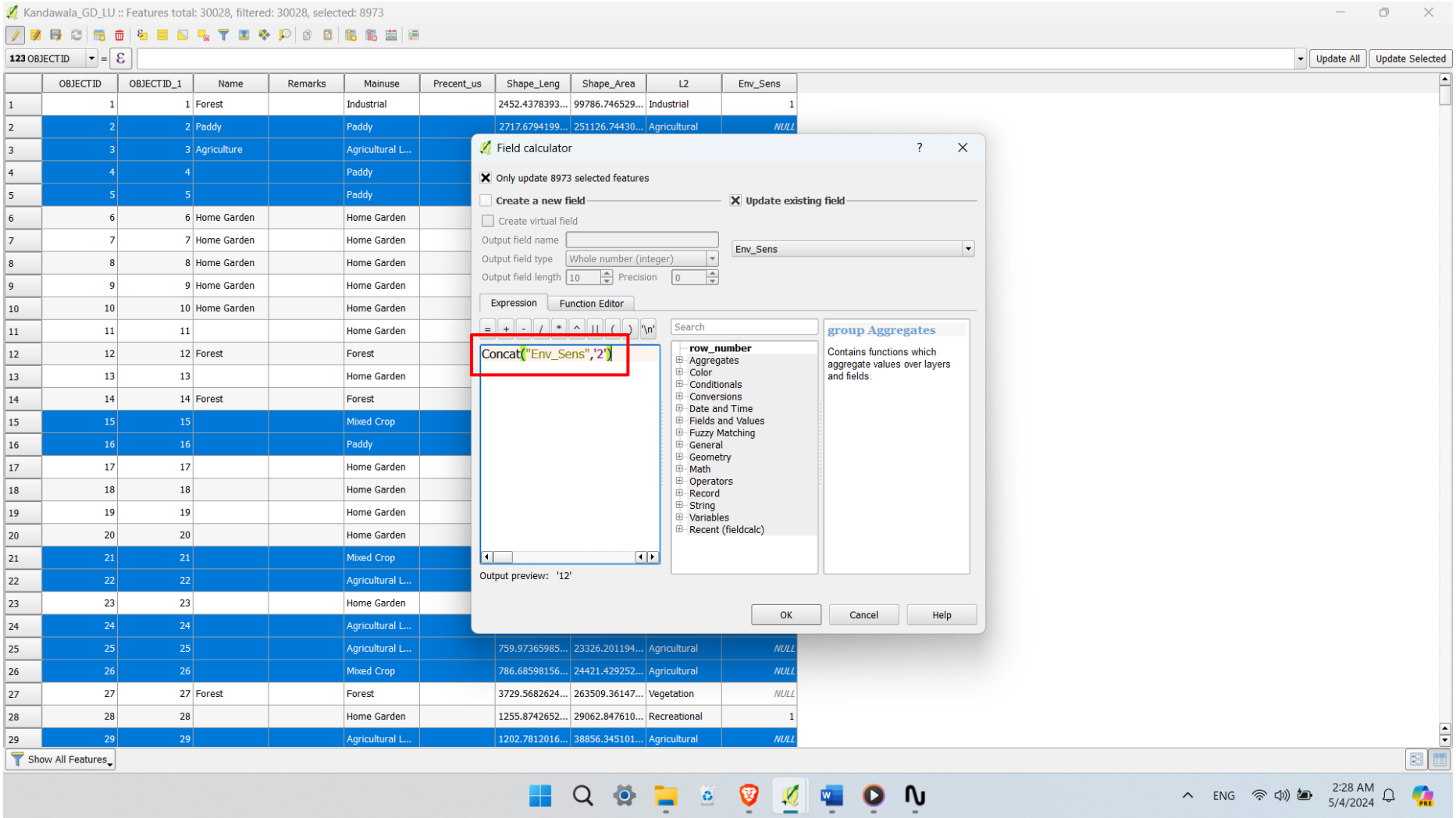


	OBJECTID	OBJECTID_1	Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2	Env_Sens
1	1	1	Forest		Industrial		2452.4378393...	99786.746529...	Industrial	1
2	2	2	Paddy		Paddy		2717.6794199...	251126.74430...	Agricultural	NULL
3	3	3	Agriculture		Agricultural L...		4929.1831197...	291030.99595...	Agricultural	NULL
4	4	4			Paddy		1689.1721519...	46418.289935...	Agricultural	NULL
5	5	5			Paddy		2364.4199710...	86727.679054...	Agricultural	NULL
6	6	6	Home Garden		Home Garden		814.63028272...	37431.211725...	Recreational	1
7	7	7	Home Garden		Home Garden		919.44471945...	38852.270967...	Recreational	1
8	8	8	Home Garden		Home Garden		1713.6064177...	128459.21254...	Recreational	1
9	9	9	Home Garden		Home Garden		935.08365697...	47755.462312...	Recreational	1
10	10	10	Home Garden		Home Garden		1118.6120919...	24640.226392...	Recreational	1
11	11	11			Home Garden		1201.2865415...	23049.342736...	Recreational	1
12	12	12	Forest		Forest		21616.107798...	10599354.302...	Vegetation	NULL
13	13	13			Home Garden		852.31742858...	18421.476763...	Recreational	1
14	14	14	Forest		Forest		17135.849144...	5175386.4355...	Vegetation	NULL
15	15	15			Mixed Crop		1137.0831688...	32271.862950...	Agricultural	NULL
16	16	16			Paddy		1350.5142022...	57605.559316...	Agricultural	NULL
17	17	17			Home Garden		1845.3138304...	79789.010855...	Recreational	1
18	18	18			Home Garden		1733.7183385...	138862.12720...	Recreational	1
19	19	19			Home Garden		1445.5148543...	67613.259116...	Recreational	1
20	20	20			Home Garden		2270.1932606...	58704.000606...	Recreational	1
21	21	21			Mixed Crop		1326.4450168...	40951.253578...	Agricultural	NULL
22	22	22			Agricultural L...		1969.5597131...	79753.400557...	Agricultural	NULL
23	23	23			Home Garden		1113.2412928...	49153.841875...	Recreational	1
24	24	24			Agricultural L...		783.91632547...	23770.604646...	Agricultural	NULL
25	25	25			Agricultural L...		759.97365985...	23326.201194...	Agricultural	NULL
26	26	26			Mixed Crop		786.68598156...	24421.429252...	Agricultural	NULL
27	27	27	Forest		Forest		3729.5682624...	263509.36147...	Vegetation	NULL
28	28	28			Home Garden		1255.8742652...	29062.847610...	Recreational	1
29	29	29			Agricultural L...		1202.7812016...	38856.345101...	Agricultural	NULL

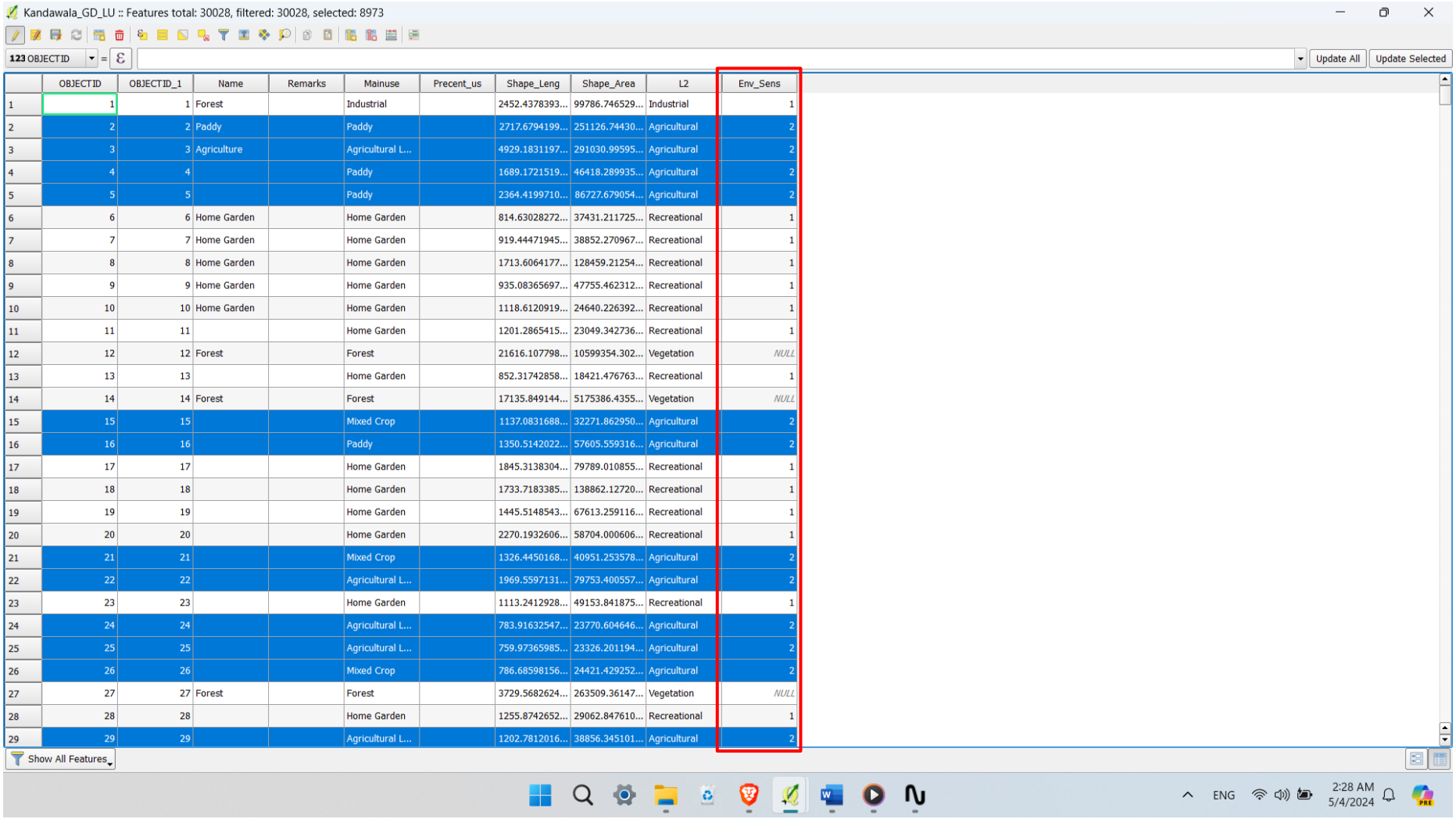
Following the same steps, select the **medium environmentally sensitive** land use categories as follows.



After selecting these, again open the field calculator and update the existing field as follows. Use the expression here as, **Concat (“Env_Sens”, ’2’)**.



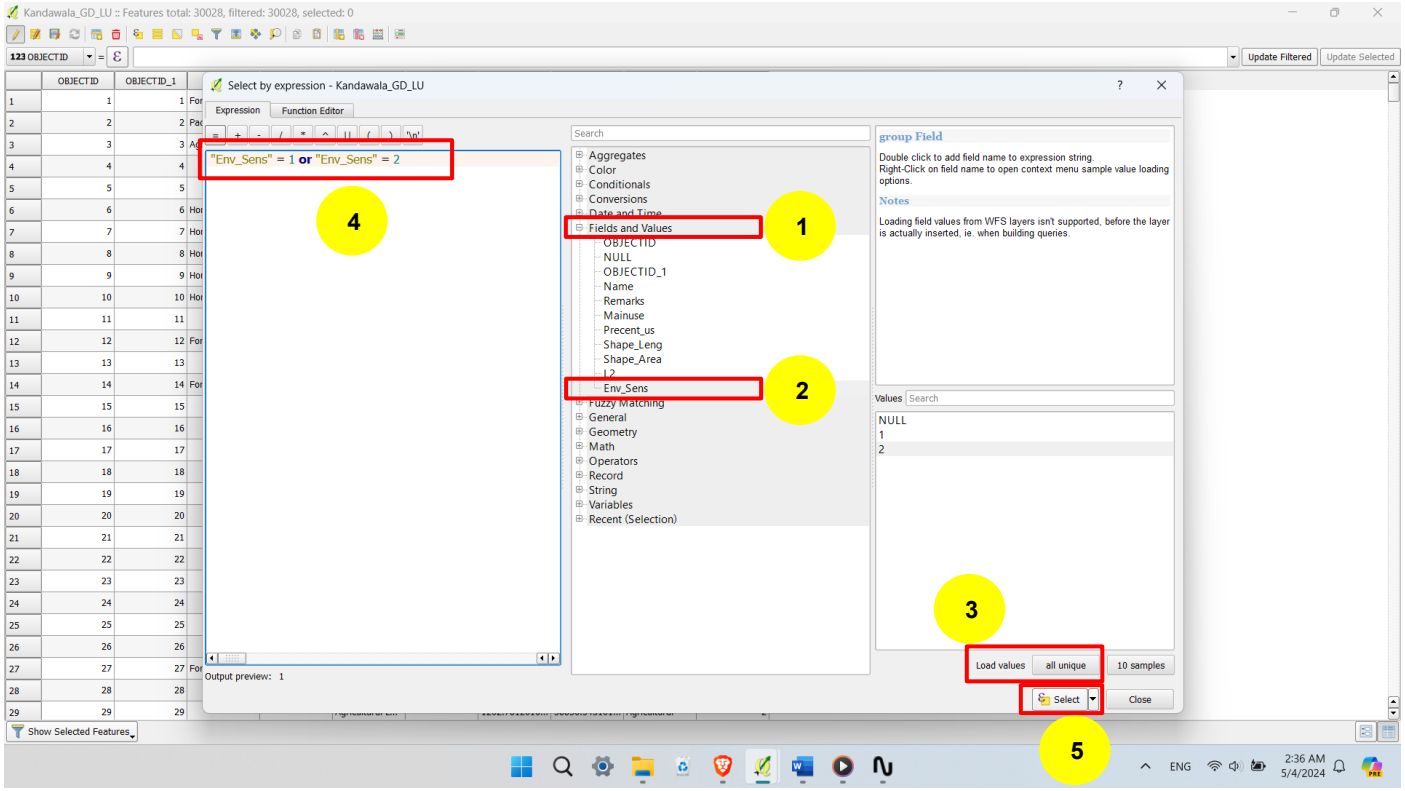
The updated field can be seen as follows. The "Env_Sens" field of the selected features shows the value "2".



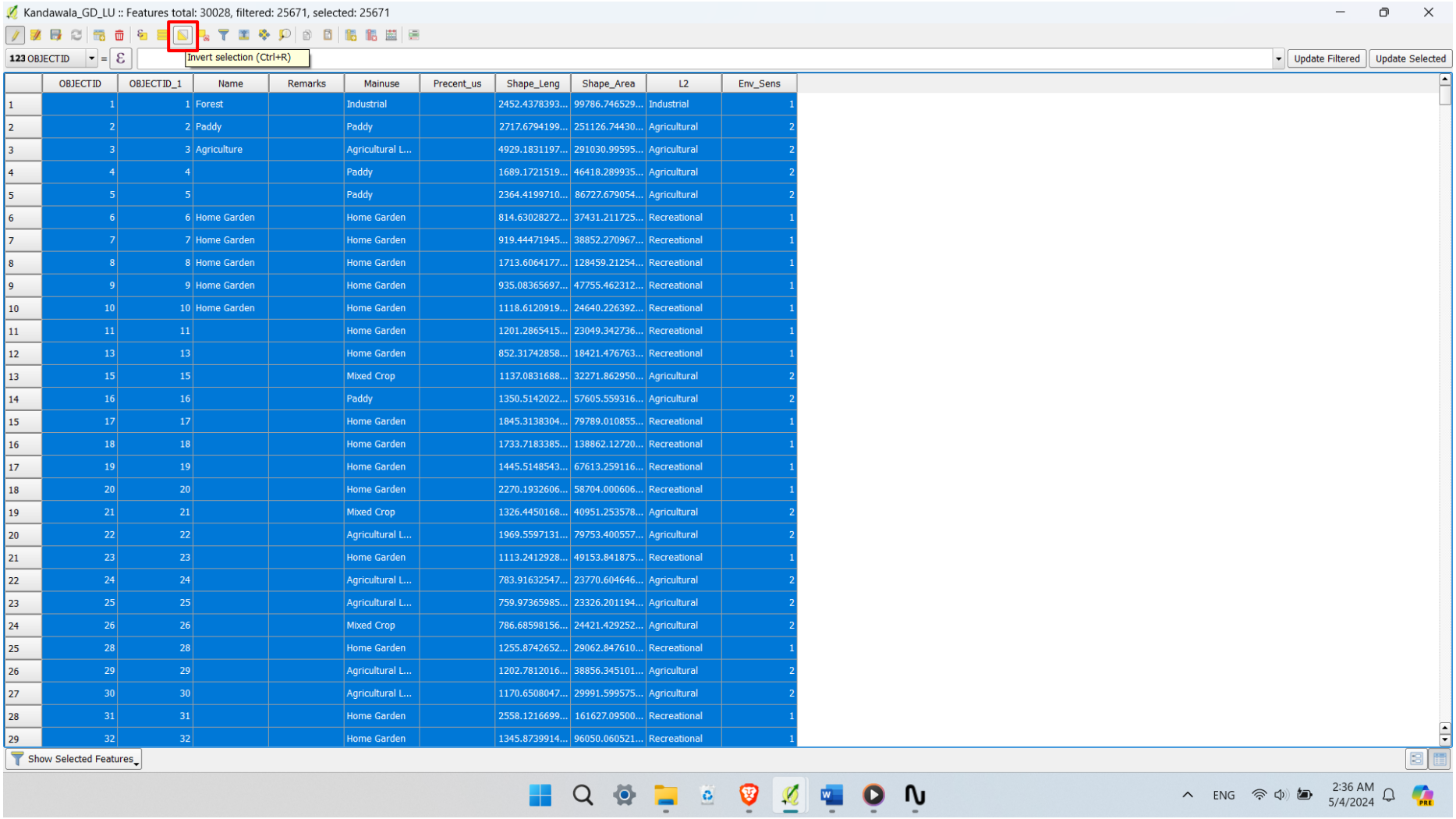
	OBJECTID	OBJECTID_1	Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2	Env_Sens
1	1	1	Forest		Industrial		2452.4378393...	99786.746529...	Industrial	1
2	2	2	Paddy		Paddy		2717.6794199...	251126.74430...	Agricultural	2
3	3	3	Agriculture		Agricultural L...		4929.1831197...	291030.99595...	Agricultural	2
4	4	4			Paddy		1689.1721519...	46418.289935...	Agricultural	2
5	5	5			Paddy		2364.4199710...	86727.679054...	Agricultural	2
6	6	6	Home Garden		Home Garden		814.63028272...	37431.211725...	Recreational	1
7	7	7	Home Garden		Home Garden		919.44471945...	38852.270967...	Recreational	1
8	8	8	Home Garden		Home Garden		1713.6064177...	128459.21254...	Recreational	1
9	9	9	Home Garden		Home Garden		935.08365697...	47755.462312...	Recreational	1
10	10	10	Home Garden		Home Garden		1118.6120919...	24640.226392...	Recreational	1
11	11	11			Home Garden		1201.2865415...	23049.342736...	Recreational	1
12	12	12	Forest		Forest		21616.107798...	10599354.302...	Vegetation	NULL
13	13	13			Home Garden		852.31742858...	18421.476763...	Recreational	1
14	14	14	Forest		Forest		17135.849144...	5175386.4355...	Vegetation	NULL
15	15	15			Mixed Crop		1137.0831688...	32271.862950...	Agricultural	2
16	16	16			Paddy		1350.5142022...	57605.559316...	Agricultural	2
17	17	17			Home Garden		1845.3138304...	79789.010855...	Recreational	1
18	18	18			Home Garden		1733.7183385...	138862.12720...	Recreational	1
19	19	19			Home Garden		1445.5148543...	67613.259116...	Recreational	1
20	20	20			Home Garden		2270.1932606...	58704.000606...	Recreational	1
21	21	21			Mixed Crop		1326.4450168...	40951.253578...	Agricultural	2
22	22	22			Agricultural L...		1969.5597131...	79753.400557...	Agricultural	2
23	23	23			Home Garden		1113.2412928...	49153.841875...	Recreational	1
24	24	24			Agricultural L...		783.91632547...	23770.604646...	Agricultural	2
25	25	25			Agricultural L...		759.97365985...	23326.201194...	Agricultural	2
26	26	26			Mixed Crop		786.68598156...	24421.429252...	Agricultural	2
27	27	27	Forest		Forest		3729.5682624...	263509.36147...	Vegetation	NULL
28	28	28			Home Garden		1255.8742652...	29062.847610...	Recreational	1
29	29	29			Agricultural L...		1202.7812016...	38856.345101...	Agricultural	2

All that remains is to select the **highly environmentally sensitive** land uses here. As an easy process for that, first, select low and medium environmentally sensitive land uses through "Select by the expression". For this,

1. Double-click on “**Fields and Values**” and expand it.
2. Again, double-click on “**Env_Sens**”. Then the “Env_Sens” will appear on the expression tab.
3. Click on “**all unique**” and see the uniques under “Env_Sens”.
4. Use the same expression to select low and medium environmentally sensitive land uses, **“Env_Sens” = 1 or “Env_Sens” = 2**
5. Click on “**Select**”.

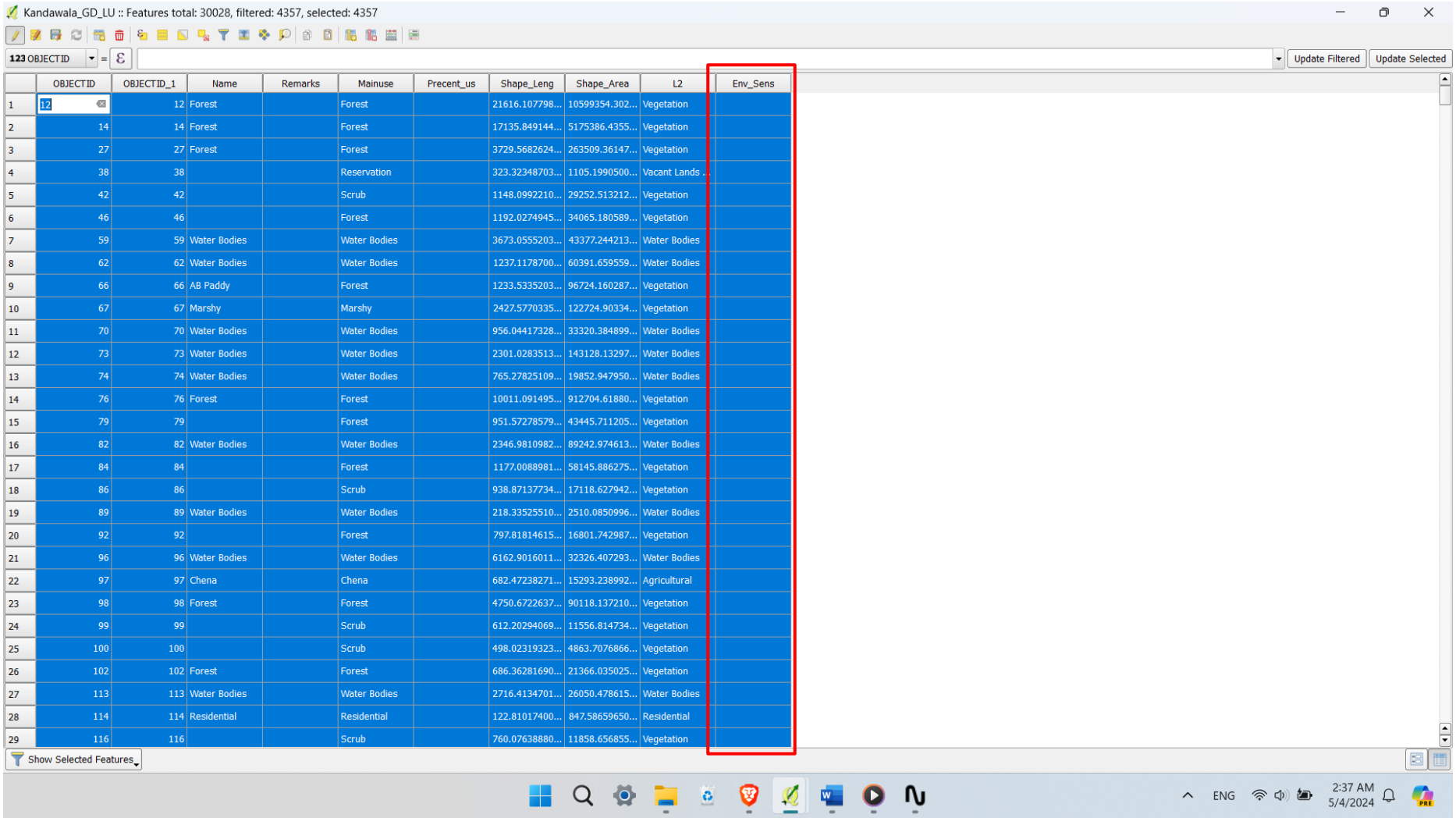


Now, all the low and medium environmentally sensitive land uses are selected on the screen. But we want to select the highly sensitive land uses here. For that, click on the "**Invert selection**" tool.



	OBJECTID	OBJECTID_1	Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2	Env_Sens
1	1	1	Forest		Industrial		2452.4378393...	99786.746529...	Industrial	1
2	2	2	Paddy		Paddy		2717.6794199...	251126.74430...	Agricultural	2
3	3	3	Agriculture		Agricultural L...		4929.1831197...	291030.99595...	Agricultural	2
4	4	4			Paddy		1689.1721519...	46418.289935...	Agricultural	2
5	5	5			Paddy		2364.4199710...	86727.679054...	Agricultural	2
6	6	6	Home Garden		Home Garden		814.63028272...	37431.211725...	Recreational	1
7	7	7	Home Garden		Home Garden		919.44471945...	38852.270967...	Recreational	1
8	8	8	Home Garden		Home Garden		1713.6064177...	128459.21254...	Recreational	1
9	9	9	Home Garden		Home Garden		935.08365697...	47755.462312...	Recreational	1
10	10	10	Home Garden		Home Garden		1118.6120919...	24640.226392...	Recreational	1
11	11	11			Home Garden		1201.2865415...	23049.342736...	Recreational	1
12	13	13			Home Garden		852.31742858...	18421.476763...	Recreational	1
13	15	15			Mixed Crop		1137.0831688...	32271.862950...	Agricultural	2
14	16	16			Paddy		1350.5142022...	57605.559316...	Agricultural	2
15	17	17			Home Garden		1845.3138304...	79789.010855...	Recreational	1
16	18	18			Home Garden		1733.7183385...	138862.12720...	Recreational	1
17	19	19			Home Garden		1445.5148543...	67613.259116...	Recreational	1
18	20	20			Home Garden		2270.1932606...	58704.000606...	Recreational	1
19	21	21			Mixed Crop		1326.4450168...	40951.253578...	Agricultural	2
20	22	22			Agricultural L...		1969.5597131...	79753.400557...	Agricultural	2
21	23	23			Home Garden		1113.2412928...	49153.841875...	Recreational	1
22	24	24			Agricultural L...		783.91632547...	23770.604646...	Agricultural	2
23	25	25			Agricultural L...		759.97365985...	23326.201194...	Agricultural	2
24	26	26			Mixed Crop		786.68598156...	24421.429252...	Agricultural	2
25	28	28			Home Garden		1255.8742652...	29062.847610...	Recreational	1
26	29	29			Agricultural L...		1202.7812016...	38856.345101...	Agricultural	2
27	30	30			Agricultural L...		1170.6508047...	29991.599575...	Agricultural	2
28	31	31			Home Garden		2558.1216699...	161627.09500...	Recreational	1
29	32	32			Home Garden		1345.8739914...	96050.060521...	Recreational	1

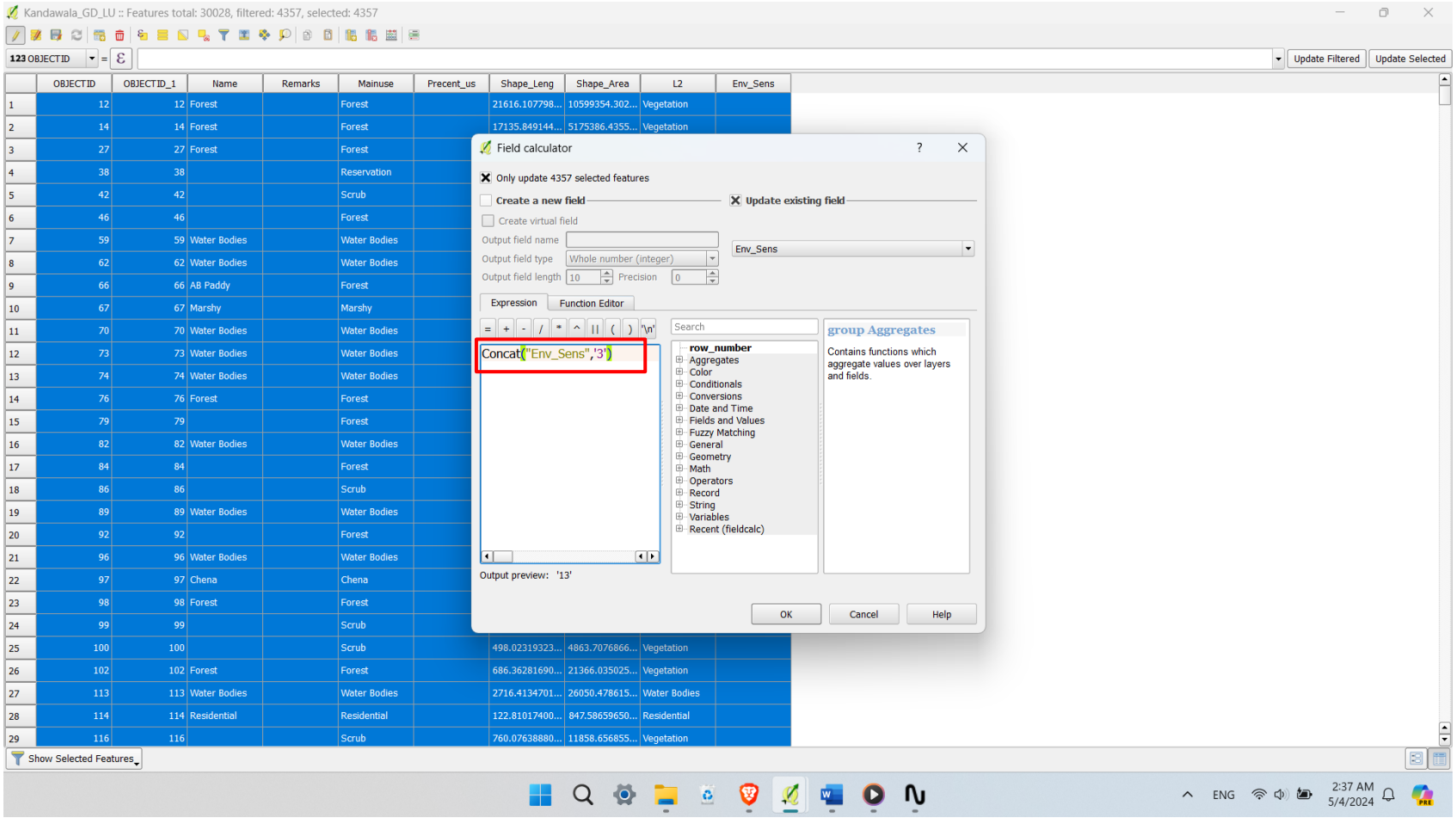
Then, the highly sensitive land uses will be automatically selected on the screen.



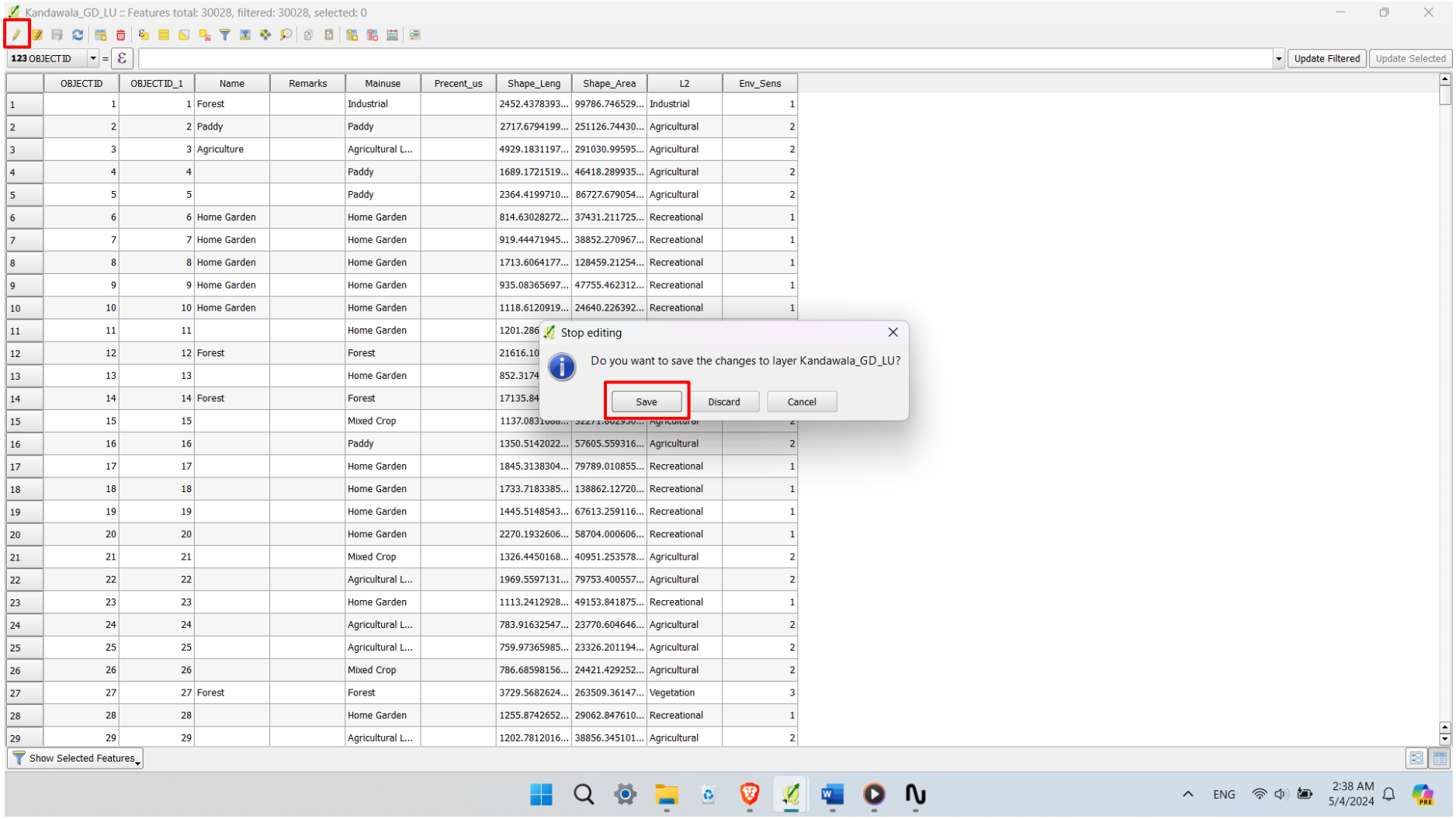
	OBJECTID	OBJECTID_1	Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2	Env_Sens
1	12	12	Forest		Forest		21616.107798...	10599354.302...	Vegetation	
2	14	14	Forest		Forest		17135.849144...	5175386.4355...	Vegetation	
3	27	27	Forest		Forest		3729.5682624...	263509.36147...	Vegetation	
4	38	38			Reservation		323.32348703...	1105.1990500...	Vacant Lands ...	
5	42	42			Scrub		1148.0992210...	29252.513212...	Vegetation	
6	46	46			Forest		1192.0274945...	34065.180589...	Vegetation	
7	59	59	Water Bodies		Water Bodies		3673.0555203...	43377.244213...	Water Bodies	
8	62	62	Water Bodies		Water Bodies		1237.1178700...	60391.659559...	Water Bodies	
9	66	66	AB Paddy		Forest		1233.5335203...	96724.160287...	Vegetation	
10	67	67	Marshy		Marshy		2427.5770335...	122724.90334...	Vegetation	
11	70	70	Water Bodies		Water Bodies		956.04417328...	33320.384899...	Water Bodies	
12	73	73	Water Bodies		Water Bodies		2301.0283513...	143128.13297...	Water Bodies	
13	74	74	Water Bodies		Water Bodies		765.27825109...	19852.947950...	Water Bodies	
14	76	76	Forest		Forest		10011.091495...	912704.61880...	Vegetation	
15	79	79			Forest		951.57278579...	43445.711205...	Vegetation	
16	82	82	Water Bodies		Water Bodies		2346.9810982...	89242.974613...	Water Bodies	
17	84	84			Forest		1177.0088981...	58145.886275...	Vegetation	
18	86	86			Scrub		938.87137734...	17118.627942...	Vegetation	
19	89	89	Water Bodies		Water Bodies		218.33525510...	2510.0850996...	Water Bodies	
20	92	92			Forest		797.81814615...	16801.742987...	Vegetation	
21	96	96	Water Bodies		Water Bodies		6162.9016011...	32326.407293...	Water Bodies	
22	97	97	Chena		Chena		682.47238271...	15293.238992...	Agricultural	
23	98	98	Forest		Forest		4750.6722637...	90118.137210...	Vegetation	
24	99	99			Scrub		612.20294069...	11556.814734...	Vegetation	
25	100	100			Scrub		498.02319323...	4863.7076866...	Vegetation	
26	102	102	Forest		Forest		686.36281690...	21366.035025...	Vegetation	
27	113	113	Water Bodies		Water Bodies		2716.4134701...	26050.478615...	Water Bodies	
28	114	114	Residential		Residential		122.81017400...	847.58659650...	Residential	
29	116	116			Scrub		760.07638880...	11858.656855...	Vegetation	

Now, we can follow the same process to enter the values for these features. Open the field calculator and update the existing field using the expression,

Concat (“Env_Sens”, ’3’).

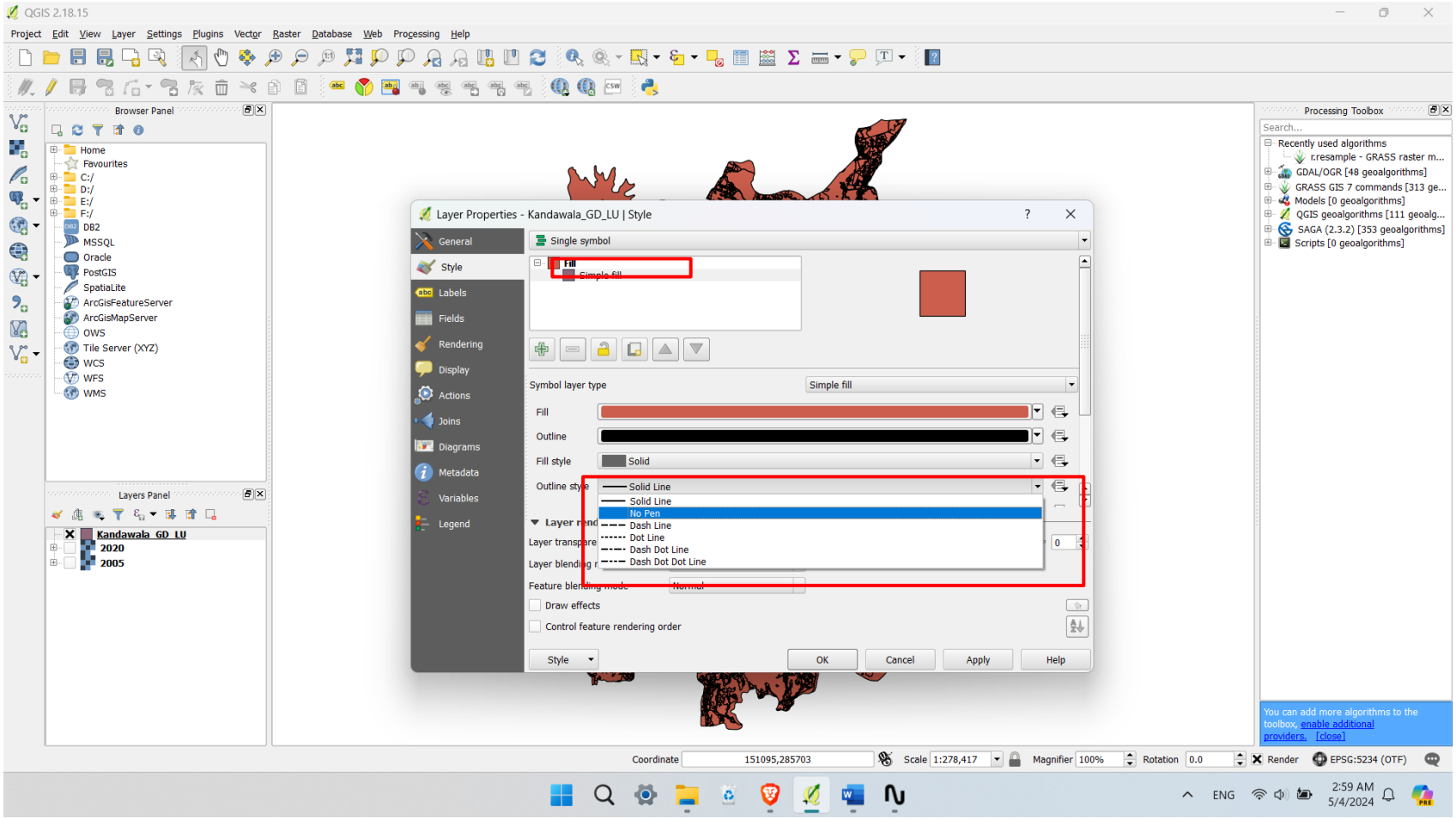


After adding these values successfully, click on the pencil icon again and save the edits.

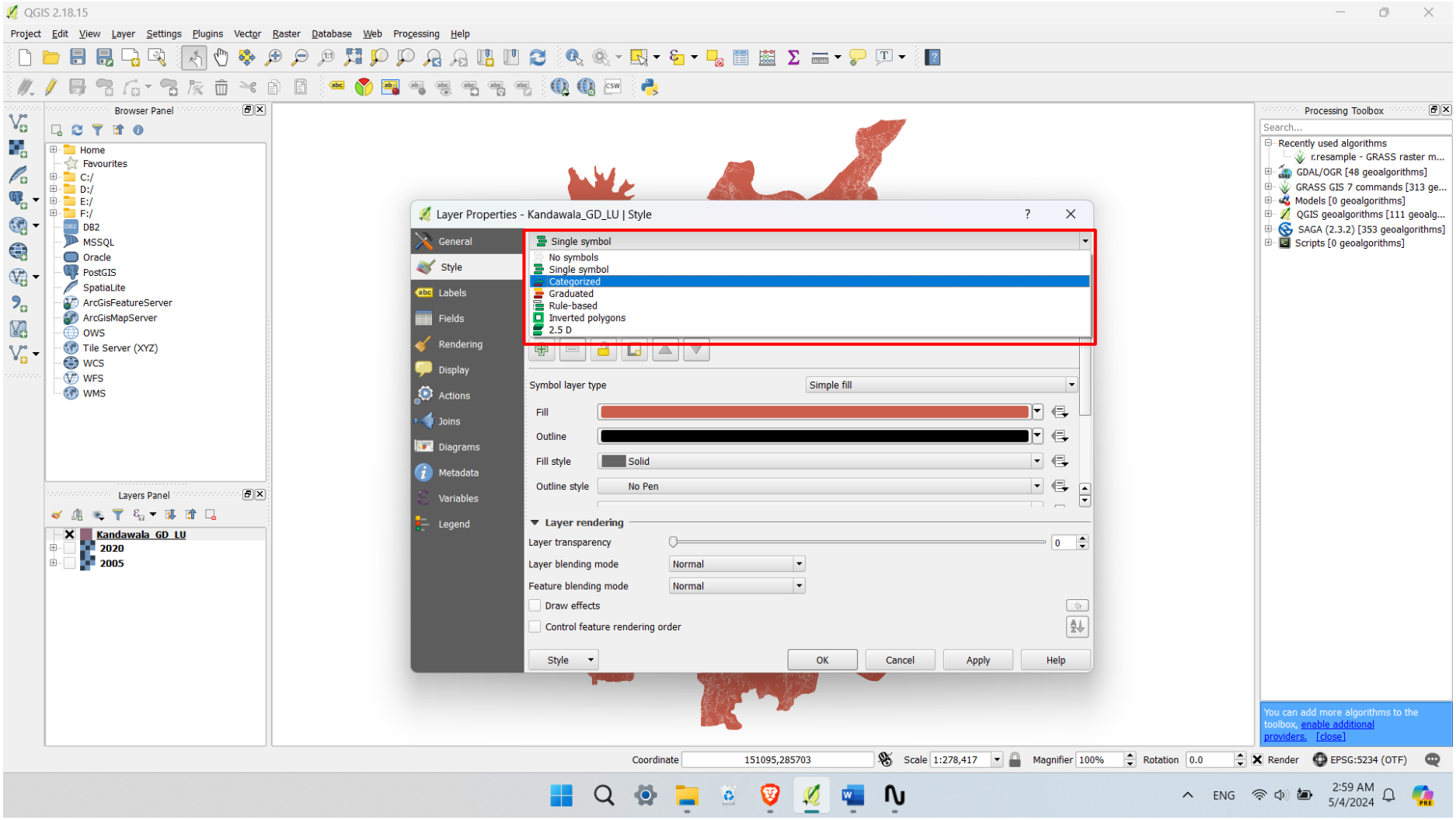


	OBJECTID	OBJECTID_1	Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2	Env_Sens
1	1	1	Forest		Industrial		2452.4378393...	99786.746529...	Industrial	1
2	2	2	Paddy		Paddy		2717.6794199...	251126.74430...	Agricultural	2
3	3	3	Agriculture		Agricultural L...		4929.1831197...	291030.99595...	Agricultural	2
4	4	4			Paddy		1689.1721519...	46418.289935...	Agricultural	2
5	5	5			Paddy		2364.4199710...	86727.679054...	Agricultural	2
6	6	6	Home Garden		Home Garden		814.63028272...	37431.211725...	Recreational	1
7	7	7	Home Garden		Home Garden		919.44471945...	38852.270967...	Recreational	1
8	8	8	Home Garden		Home Garden		1713.6064177...	128459.21254...	Recreational	1
9	9	9	Home Garden		Home Garden		935.08365697...	47755.462312...	Recreational	1
10	10	10	Home Garden		Home Garden		1118.6120919...	24640.226392...	Recreational	1
11	11	11			Home Garden		1201.286			
12	12	12	Forest		Forest		21616.10			
13	13	13			Home Garden		852.3174			
14	14	14	Forest		Forest		17135.84			
15	15	15			Mixed Crop		1137.0831088...	32271.602950...	Agricultural	2
16	16	16			Paddy		1350.5142022...	57605.559316...	Agricultural	2
17	17	17			Home Garden		1845.3138304...	79789.010855...	Recreational	1
18	18	18			Home Garden		1733.7183385...	138862.12720...	Recreational	1
19	19	19			Home Garden		1445.5148543...	67613.259116...	Recreational	1
20	20	20			Home Garden		2270.1932606...	58704.000606...	Recreational	1
21	21	21			Mixed Crop		1326.4450168...	40951.253578...	Agricultural	2
22	22	22			Agricultural L...		1969.5597131...	79753.400557...	Agricultural	2
23	23	23			Home Garden		1113.2412928...	49153.841875...	Recreational	1
24	24	24			Agricultural L...		783.91632547...	23770.604646...	Agricultural	2
25	25	25			Agricultural L...		759.97365985...	23326.201194...	Agricultural	2
26	26	26			Mixed Crop		786.68598156...	24421.429252...	Agricultural	2
27	27	27	Forest		Forest		3729.5682624...	263509.36147...	Vegetation	3
28	28	28			Home Garden		1255.8742652...	29062.847610...	Recreational	1
29	29	29			Agricultural L...		1202.7812016...	38856.345101...	Agricultural	2

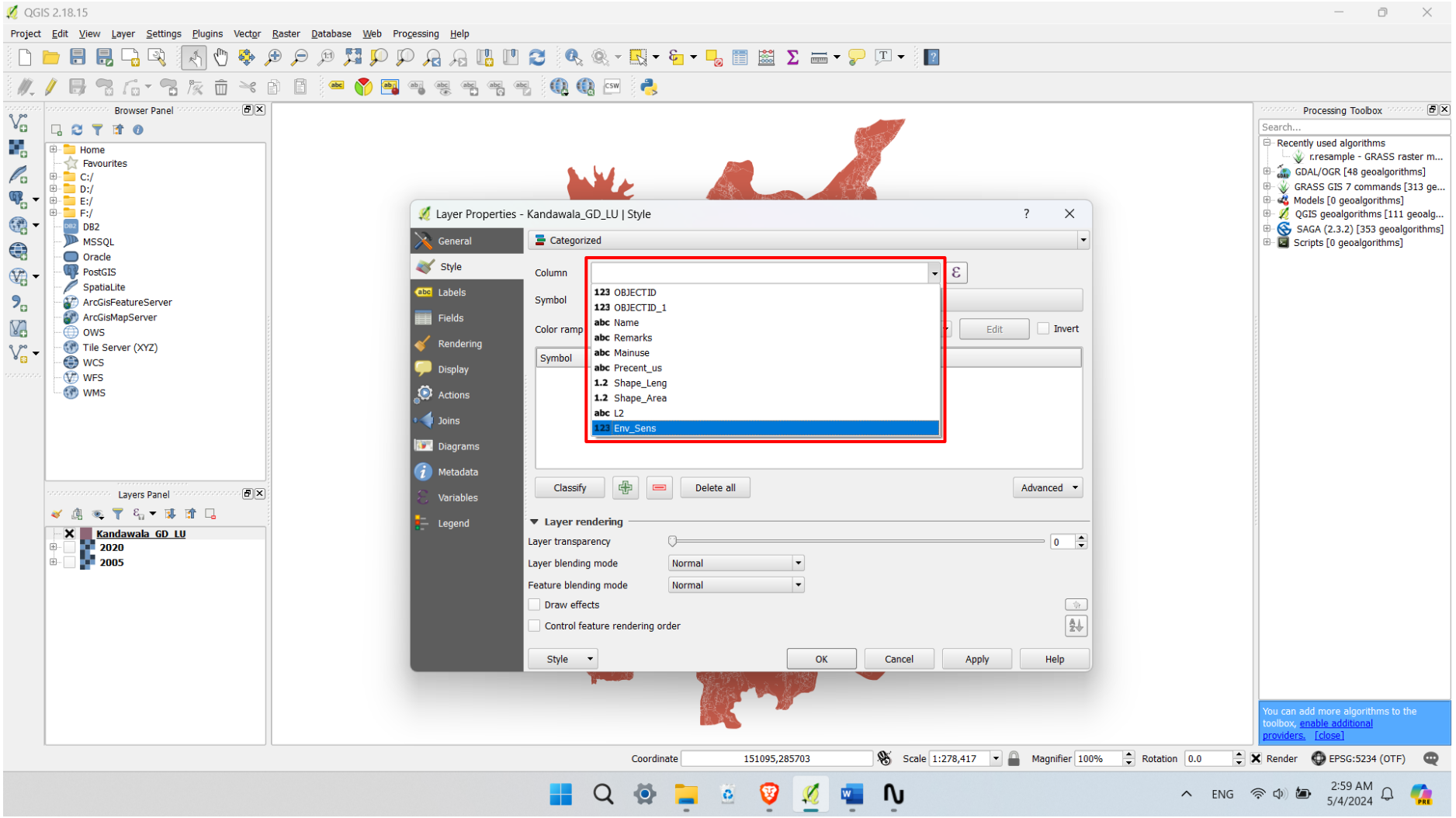
After saving the edits, open the layer properties and go to the "**Style properties**". Next, click on "**Simple fill**". Then expand the "**Outline style**" and select "**No Pen**". After that, click on "**Apply**" and "**OK**". Outlines of the vector layer will be removed from this process.



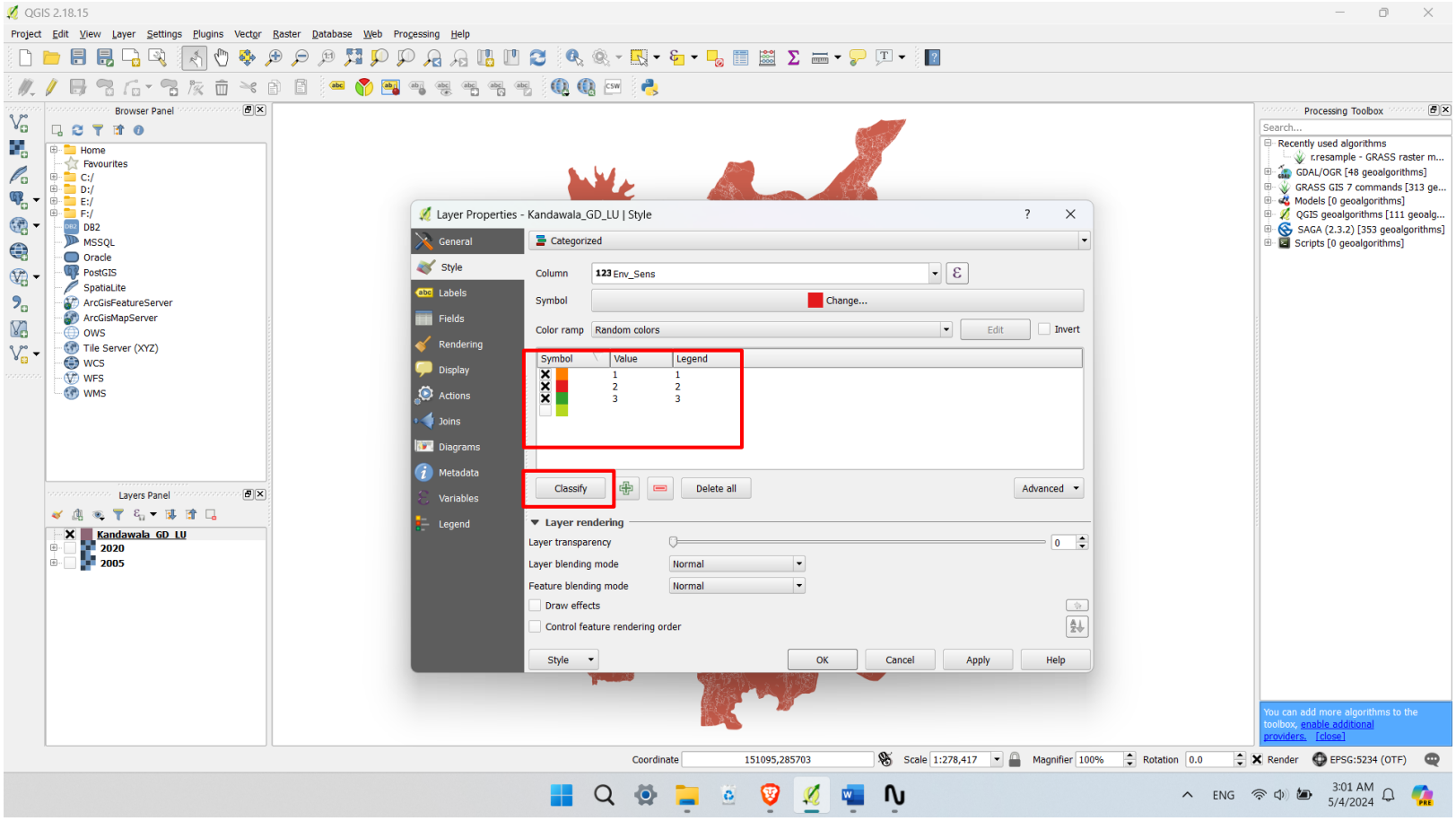
Let's categorize this vector layer. For that, click on "**Single symbol**" and expand it. Select "**Categorized**" from the expanded list.


QGIS 2.18.15
Project Edit View Layer Settings Plugins Vector Raster Database Web Processing Help
Browser Panel
Home
Favourites
C:/
D:/
E:/
F:/
DB2
MSSQL
Oracle
PostGIS
SpatiaLite
ArcGisFeatureServer
ArcGisMapServer
OWS
Tile Server (XYZ)
WCS
WFS
WMS
Layers Panel
Kandawala_GD_LU
2020
2005
Layer Properties - Kandawala_GD_LU | Style
General
Style
Labels
Fields
Rendering
Display
Actions
Joins
Diagrams
Metadata
Variables
Legend
Single symbol
No symbols
Single symbol
Categorized
Graduated
Rule-based
Inverted polygons
2.5 D
Symbol layer type
Simple fill
Fill
Outline
Fill style
Solid
Outline style
No Pen
Layer rendering
Layer transparency
Layer blending mode
Normal
Feature blending mode
Normal
Draw effects
Control feature rendering order
Style
OK
Cancel
Apply
Help
Processing Toolbox
Search...
Recently used algorithms
r.resample - GRASS raster m...
GDAL/OGR [48 geoalgorithms]
GRASS GIS 7 commands [313 ge...
Models [0 geoalgorithms]
QGIS geoalgorithms [111 geoalg...
SAGA (2.3.2) [353 geoalgorithms]
Scripts [0 geoalgorithms]
You can add more algorithms to the toolbox, enable additional providers. [close]
Coordinate 151095,285703
Scale 1:278,417
Magnifier 100%
Rotation 0.0
Render
EPSG:5234 (OTF)
ENG
2:59 AM
5/4/2024

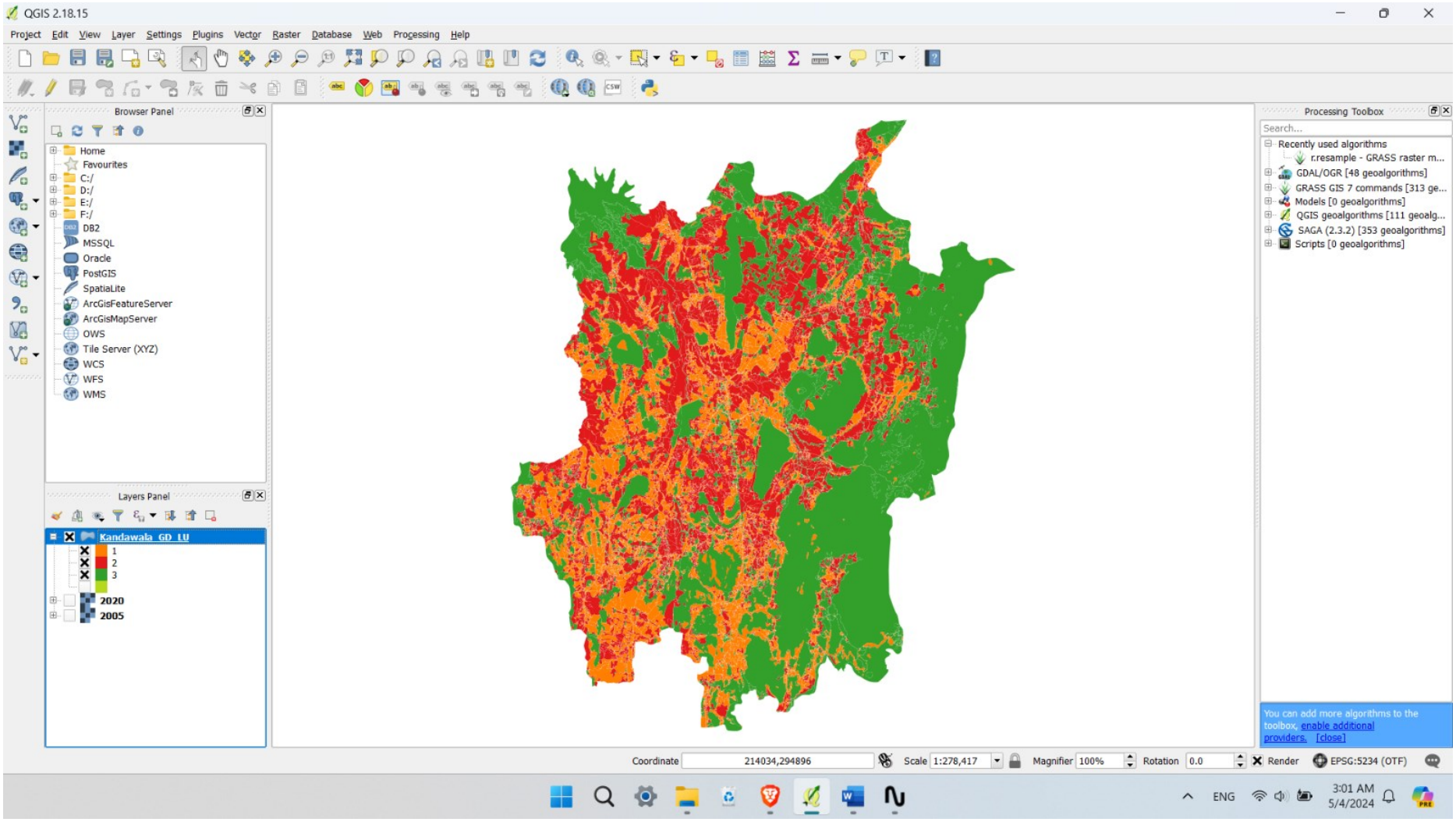
Next, expand the option “**Column**”, and select the field “**Env_Sens**”.



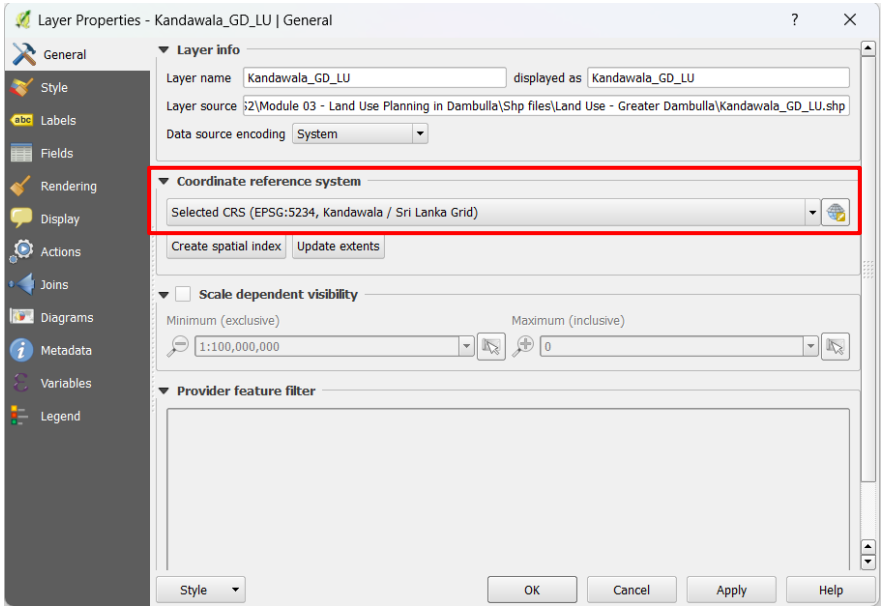
Click on “**Classify**”, then the classification will be displayed as follows. If you want to change the colors of each category, click on the color and select the color that you want.



Here is the classification according to the environmental sensitivity of the Dambulla region.



Next, we have to check the coordinate reference system and other requirements as the above land use layers. First, check the coordinate reference system as follows. If it is not match with the above land use layers, take the necessary actions to change it.



And as before, this vector layer needs to be converted into a raster layer. After that, if the cell size, rows, and column values are not the same, the resampling process has to be done. In this way, you can prepare the layer for the environmental sensitivity of the Dambulla area.

2. Road Density

Road density plays a pivotal role and can significantly influence land use patterns. Road density is a vital factor in land use simulation due to its profound influence on economic activity, urban expansion, environmental sustainability, and public service provision. By incorporating road density into land use models, planners, and policymakers can make more informed decisions that balance development needs with environmental and social considerations. This holistic approach ensures that land use planning supports sustainable and resilient urban and rural development.

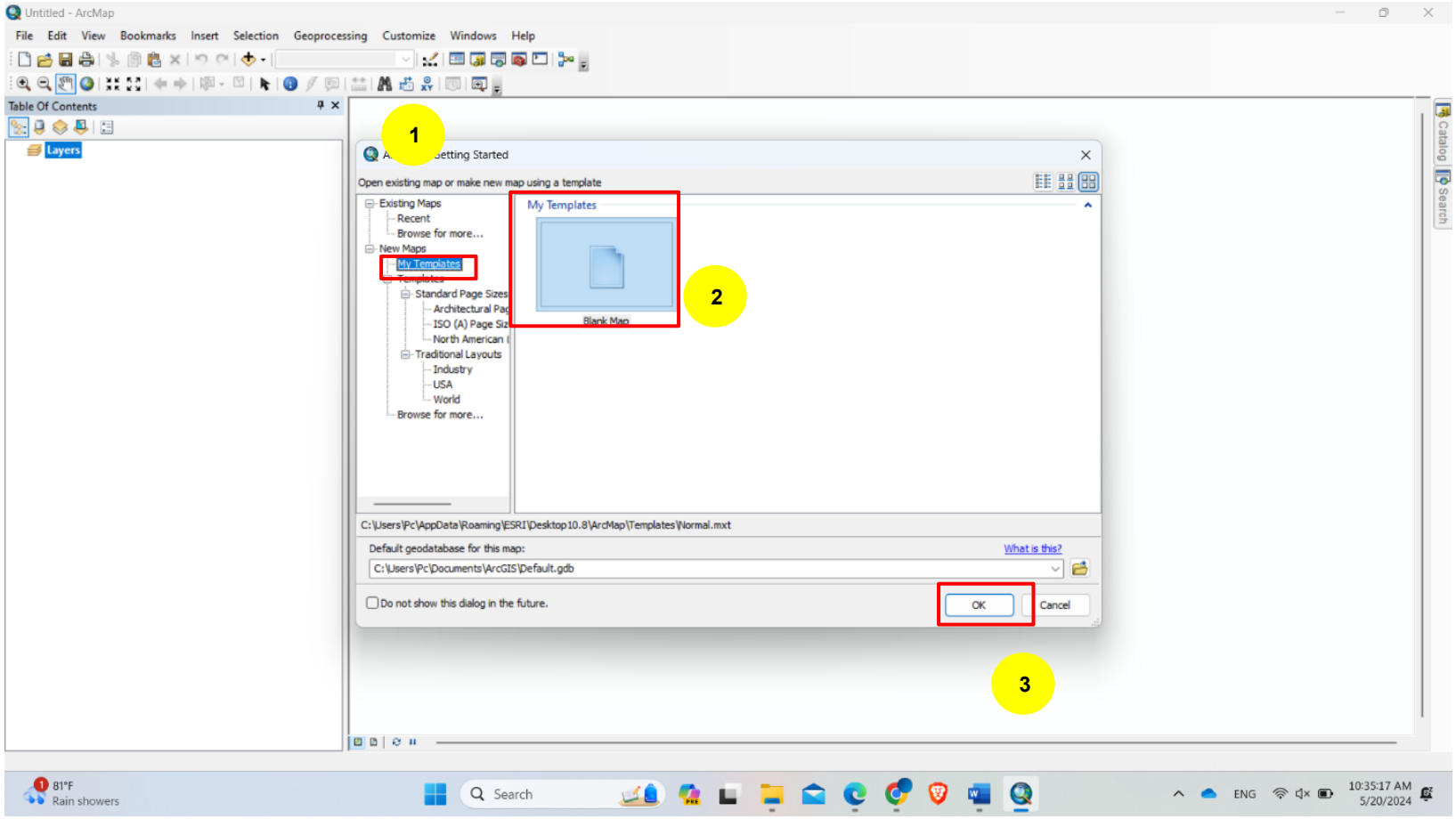
Initially, this book was developed using QGIS, an open-source GIS software. However, we have now transitioned to using ArcMap, which is not open source. The reason for this change is that QGIS cannot easily create road density layers, whereas ArcMap offers advanced tools that make this process straightforward and efficient. This adjustment ensures that the book remains practical and effective for users needing detailed road density analysis in their land use simulations.

1. Opening ArcMap

To create this layer, first, open Arc Map software.

Starting a New Map

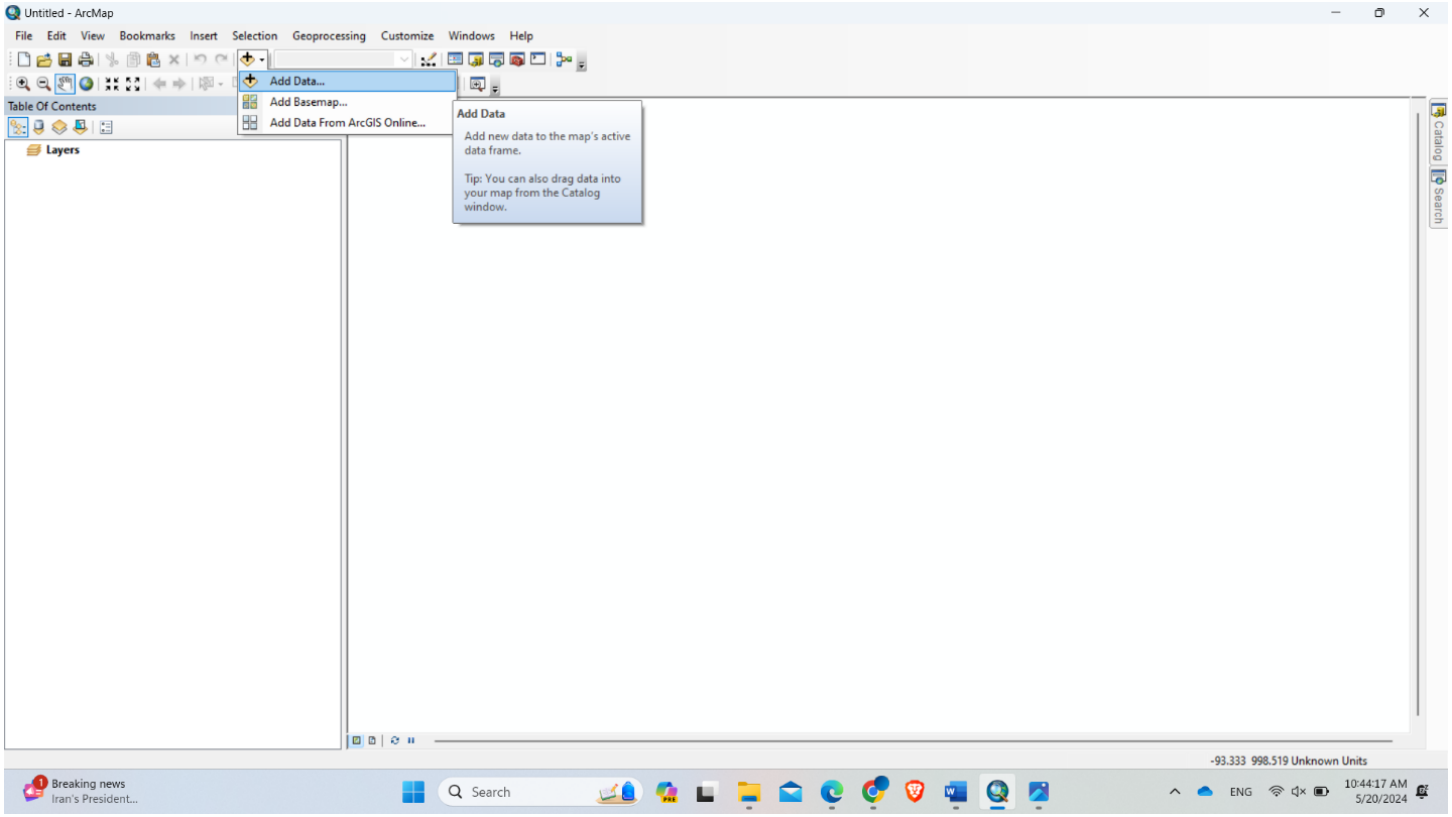
In the ArcMap startup dialog box, you can choose to open an existing map or start a new one. To create a new map, select "**Blank Map**" from "**My Templates**" and click "**OK**". This will open a blank map document where you can add and work with spatial data.



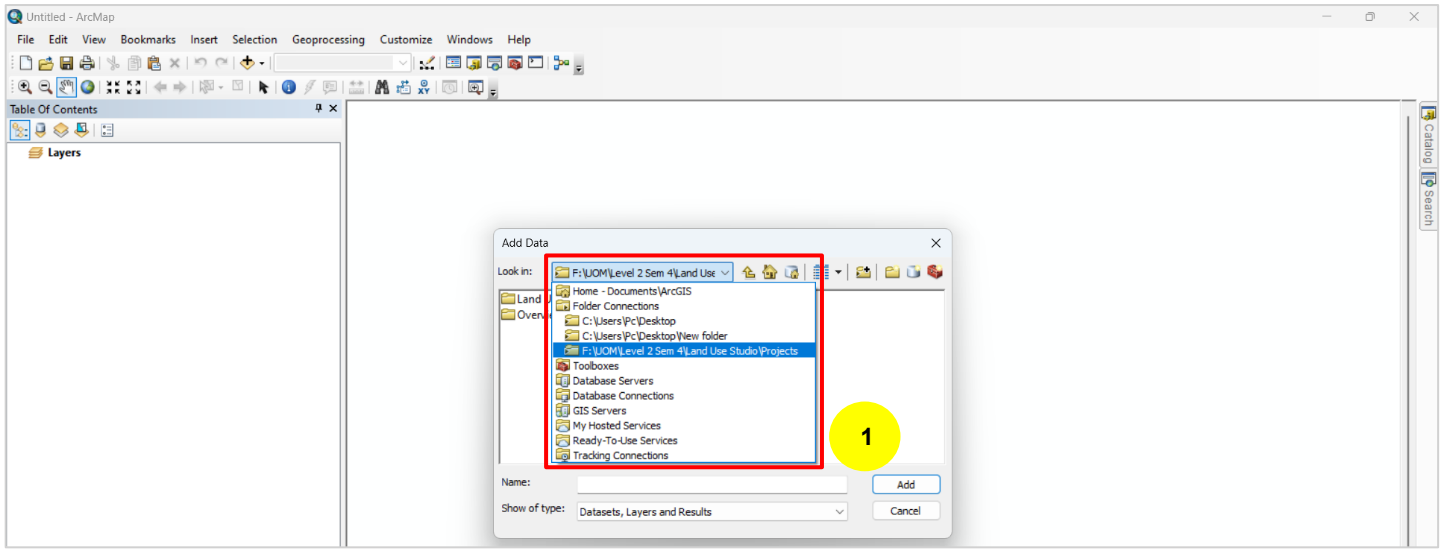
2. Adding a Shapefile

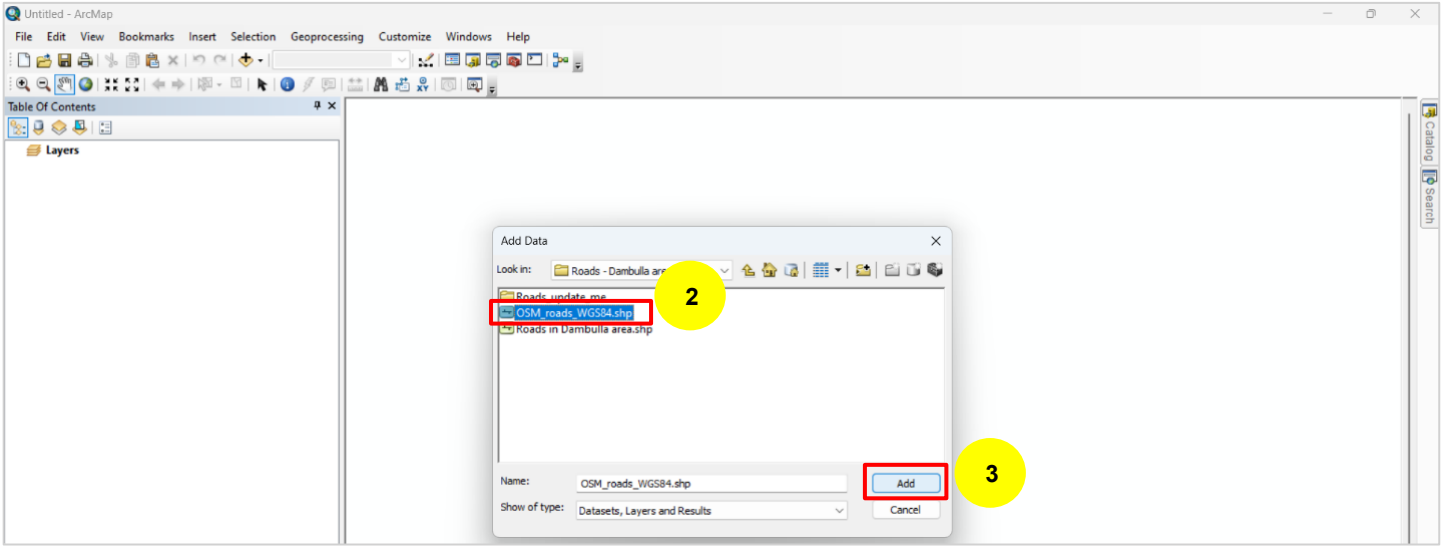
To add a shapefile, first ensure that your shapefile (.shp) and its associated files (.shx, .dbf, etc.) are saved in an accessible directory on your computer.

In ArcMap, go to the "**File**" menu and select "**Add Data**". Alternatively, you can click the "Add Data" button (represented by a plus sign icon) on the Standard toolbar.

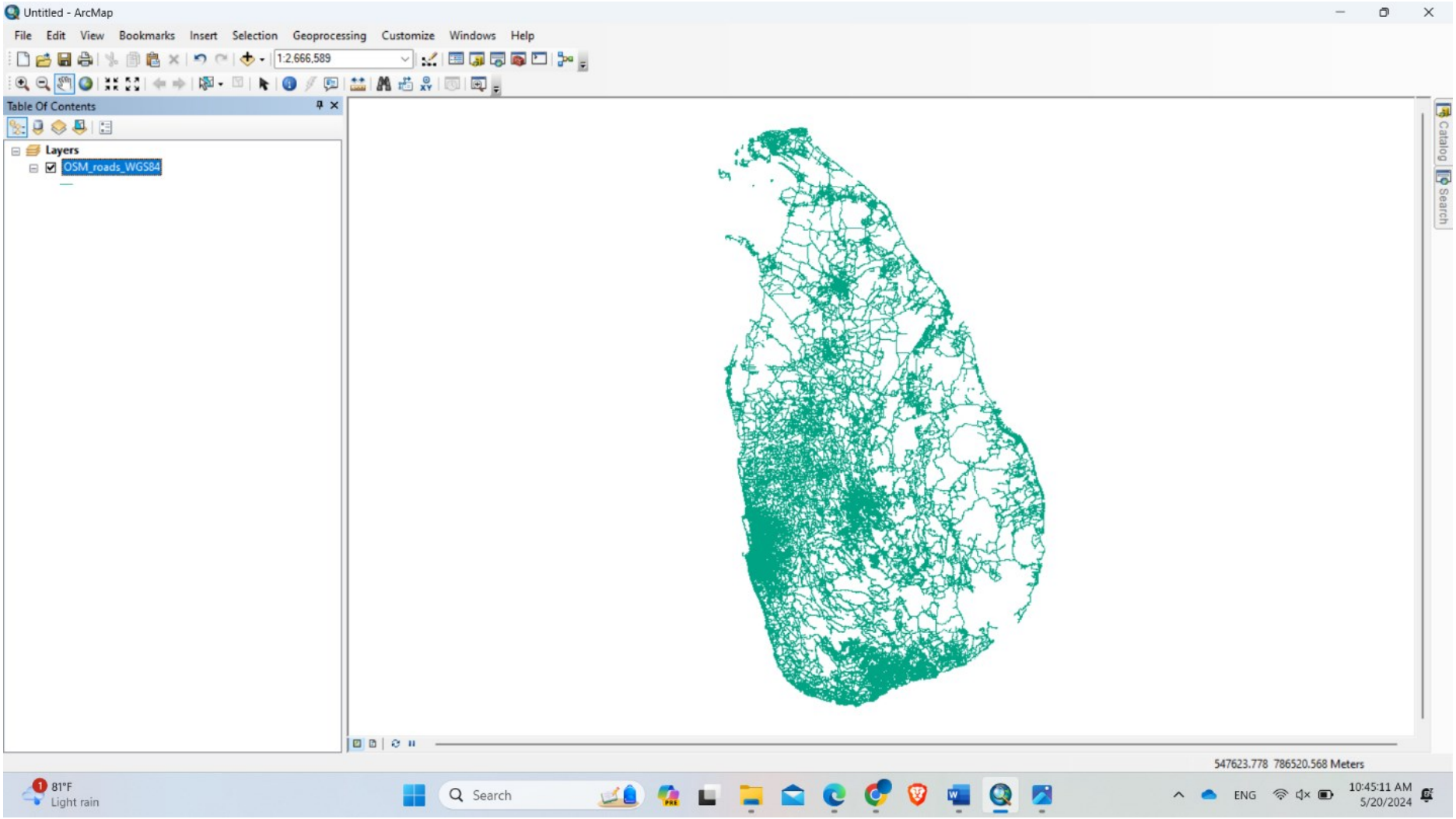


In the Add Data dialog box, navigate to the location of your shapefile. Select the shapefile you wish to add and click "**Add**".

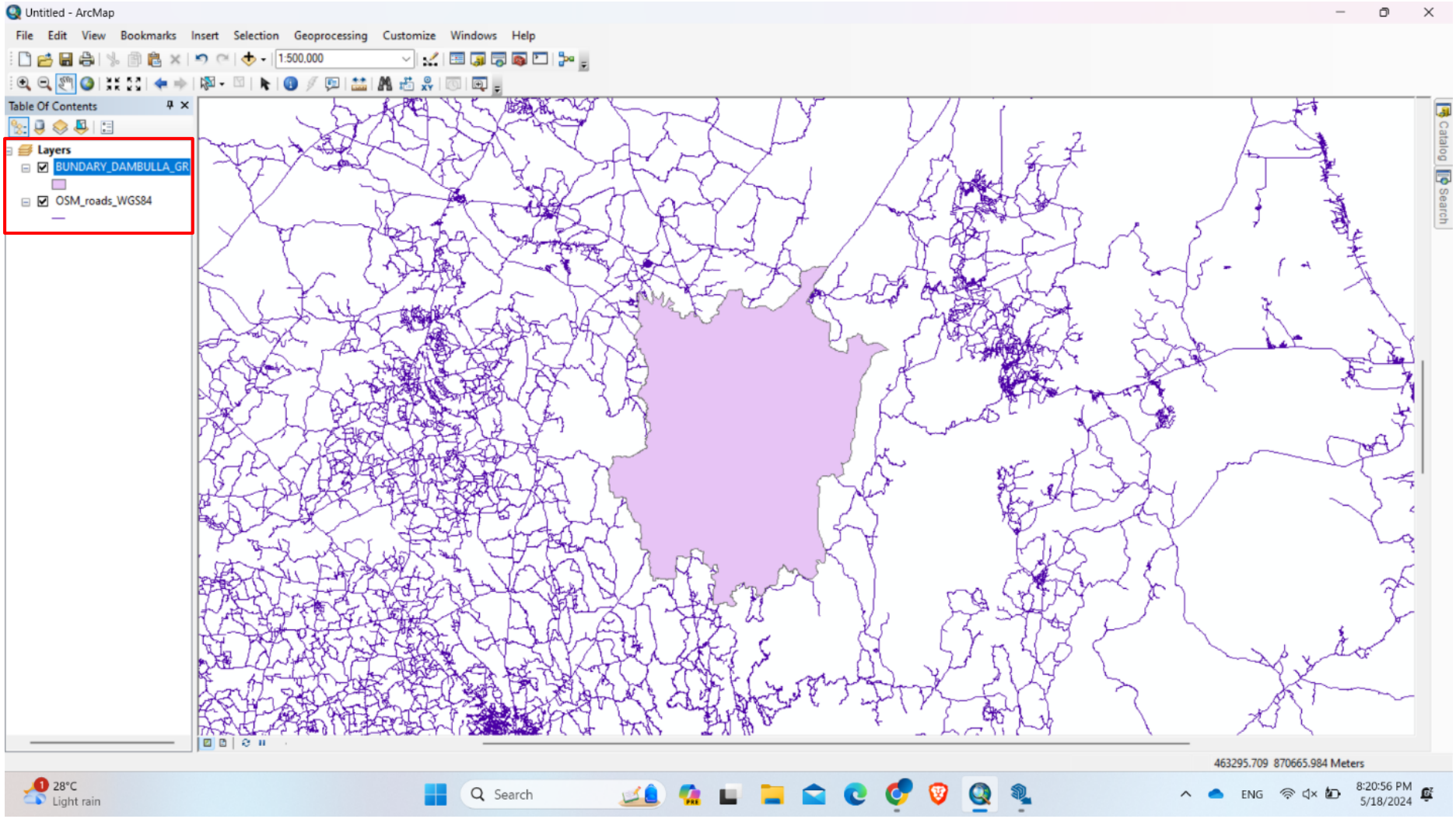

Untitled - ArcMap
File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
Table Of Contents
Layers
Add Data
Look in:
F:\UOM\Level 2 Sem 4\Land Use
Home - Documents\ArcGIS
Folder Connections
C:\Users\Pc\Desktop
C:\Users\Pc\Desktop\New folder
F:\UOM\Level 2 Sem 4\Land Use Studio\Projects
Toolboxes
Database Servers
Database Connections
GIS Servers
My Hosted Services
Ready-To-Use Services
Tracking Connections
1
Name:
Add
Show of type:
Datasets, Layers and Results
Cancel
Catalog
Search


Untitled - ArcMap
File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
Table Of Contents
Layers
Add Data
Look in:
Roads - Dambulla ar
OSM_roads_WGS84.shp
Roads in Dambulla area.shp
2
Name:
OSM_roads_WGS84.shp
Add
3
Show of type:
Datasets, Layers and Results
Cancel
Catalog
Search

The shapefile will now appear as a new layer in the Table of Contents on the left side of the ArcMap interface, and its data will be displayed on the map. For that, have added the road layer of Sri Lanka, which was downloaded from **Open Street Map**.



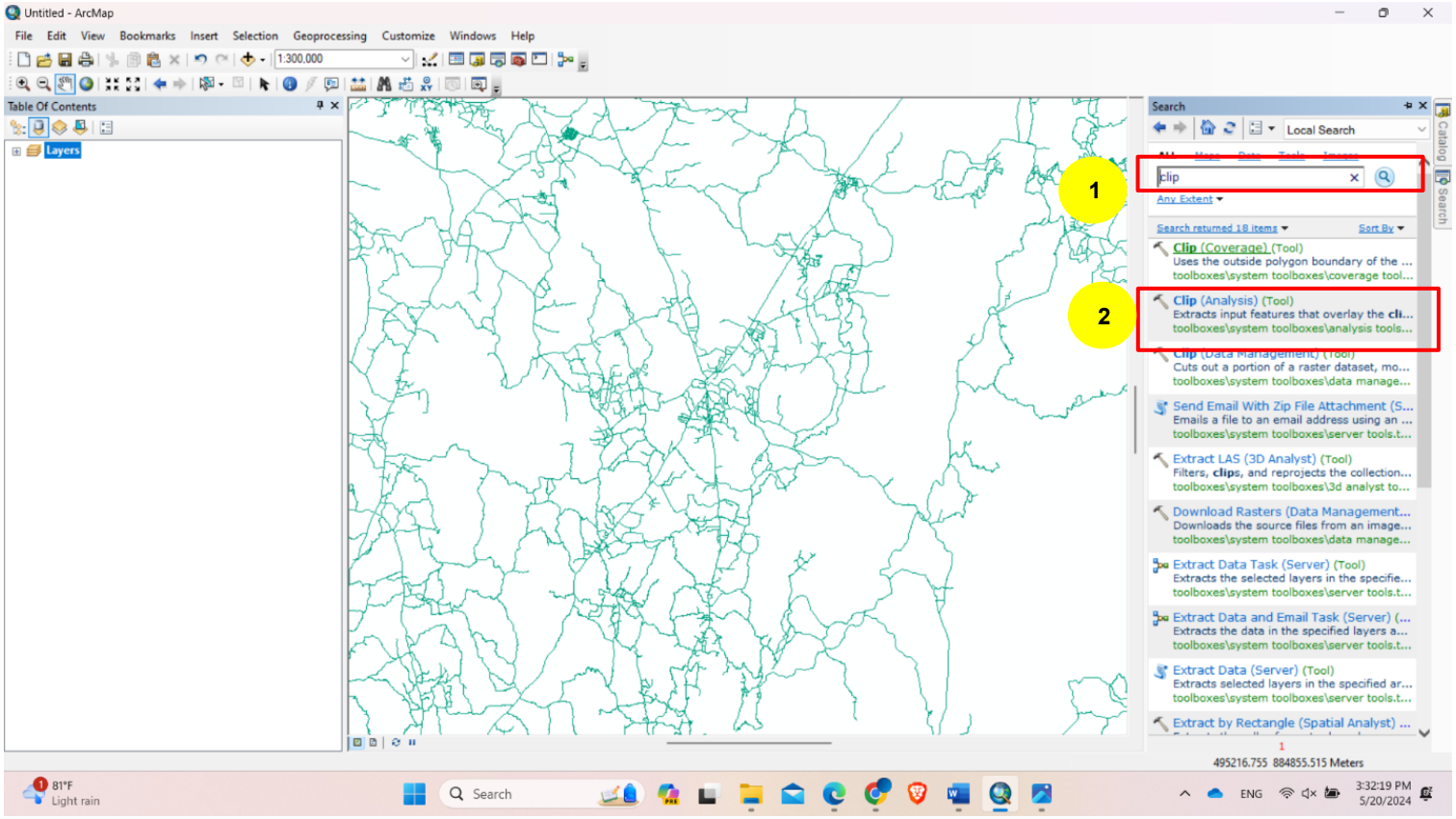
In the same way, the boundary (.shp) file created for the greater Dambulla area was imported. Now there are 2 layers in the workspace.



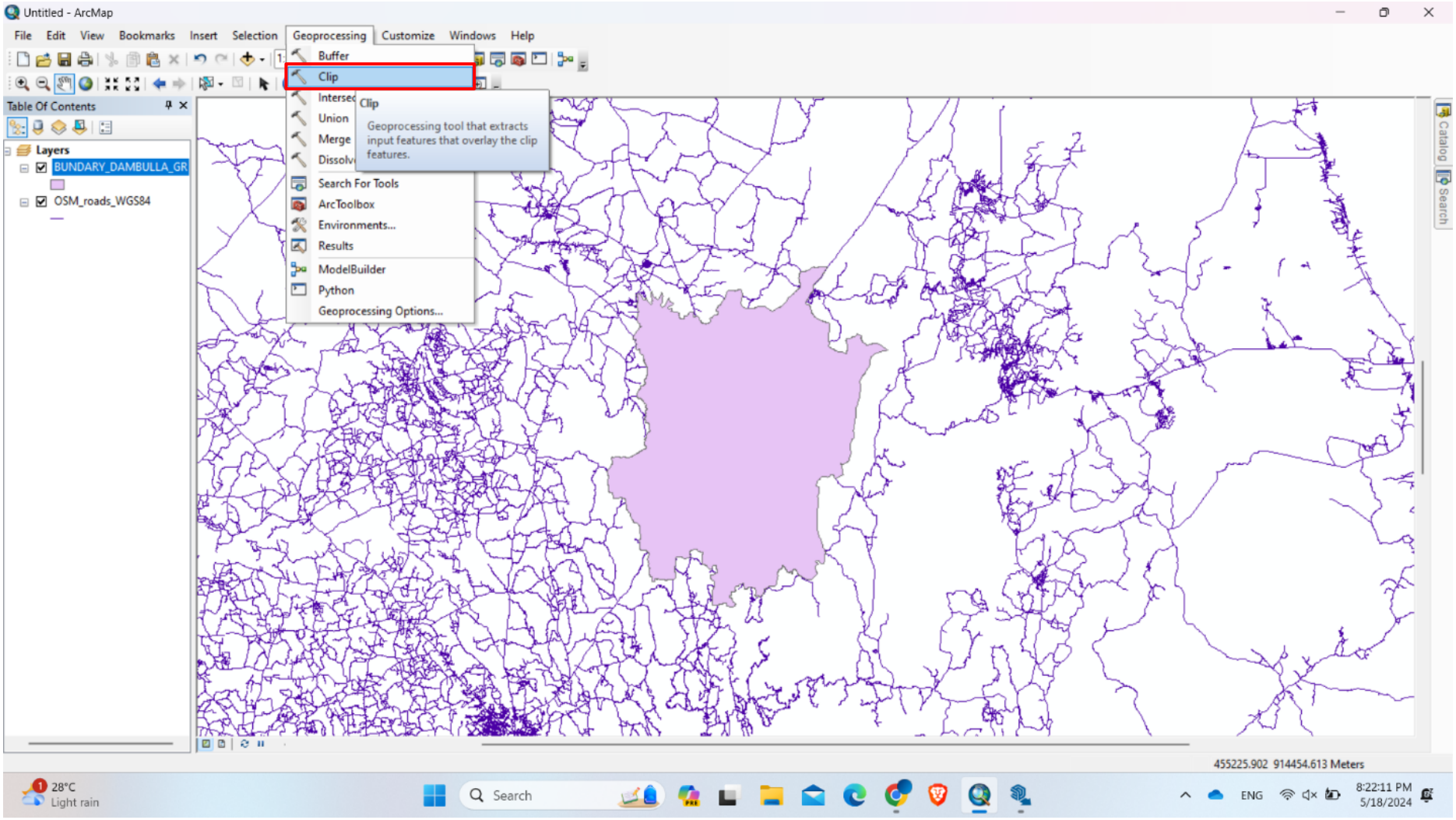
3. **Run the Clip Tool.**

Then use the clip tool to select the road layer only for the relevant area. Go to the "**Geoprocessing**" menu at the top of the ArcMap interface and select "**Clip**". Alternatively, you can search for the Clip tool in the "**Search**" window or access it through "**ArcToolbox**" by navigating to,

Analysis Tools > Extract > Clip.



Or select **Geoprossessing > Clip**



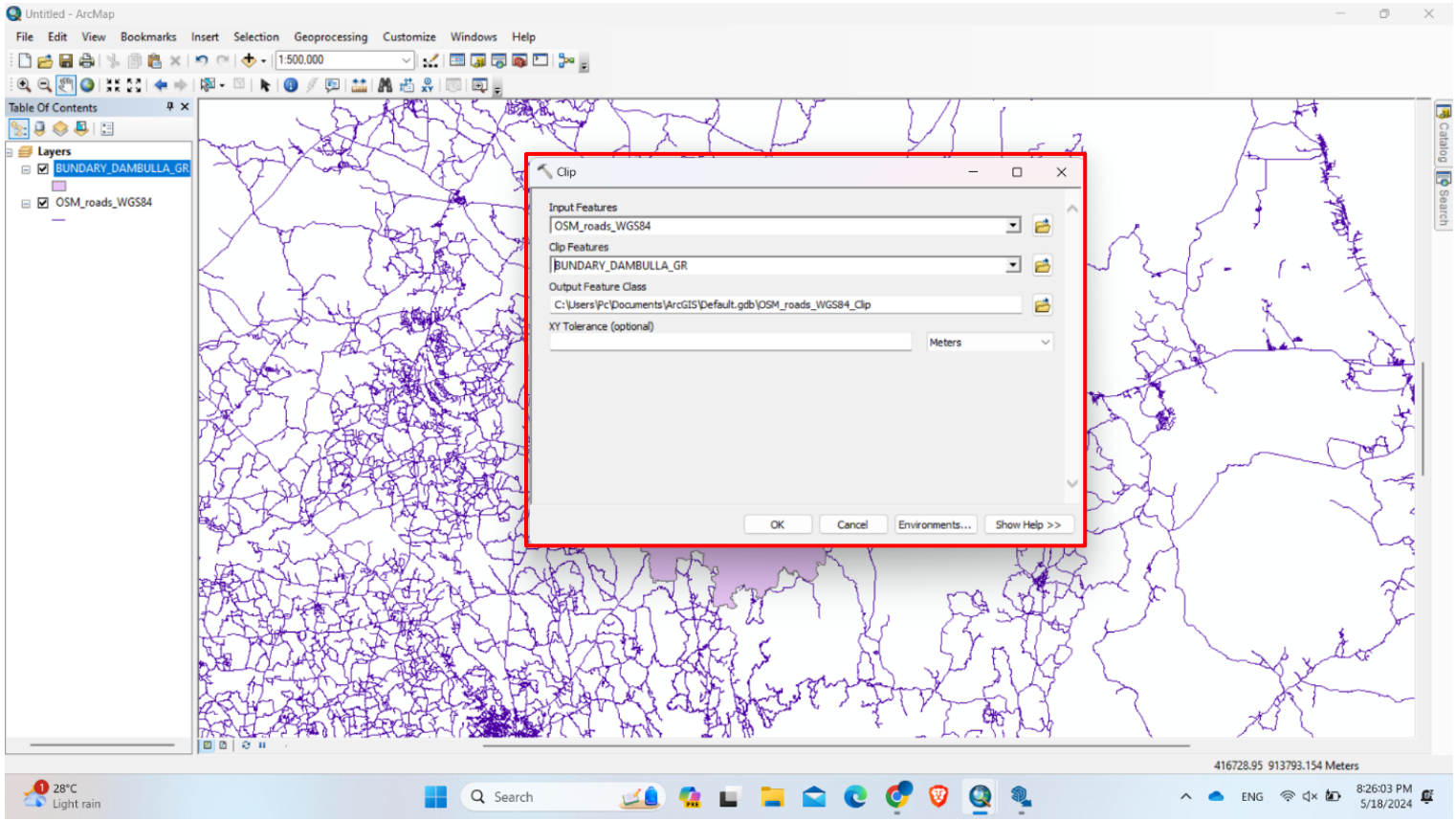
I. In the Clip tool dialog box, set the following parameters.

II. **Input Features:** Select your road layer (the layer you want to clip).

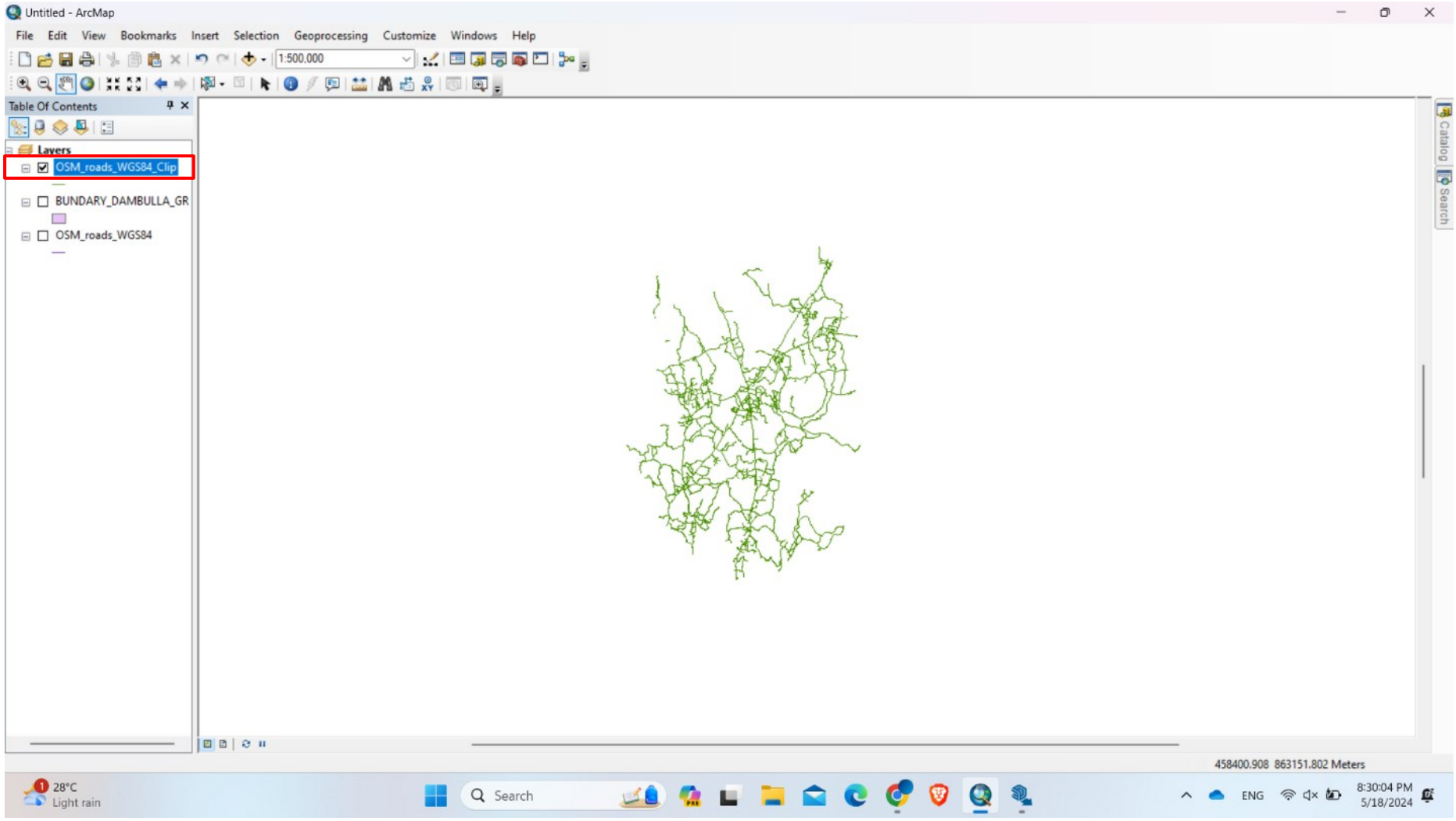
III. **Clip Features:** Select your boundary shapefile (the area you want to clip to).

IV. **Output Feature Class:** Specify the location and name for the output clipped layer. Click the folder icon to navigate to the desired save location and provide a name for the new shapefile.

After setting the parameters, click "**OK**" to run the Clip tool. The tool will process the data and create a new clipped road layer based on the boundary you provided.

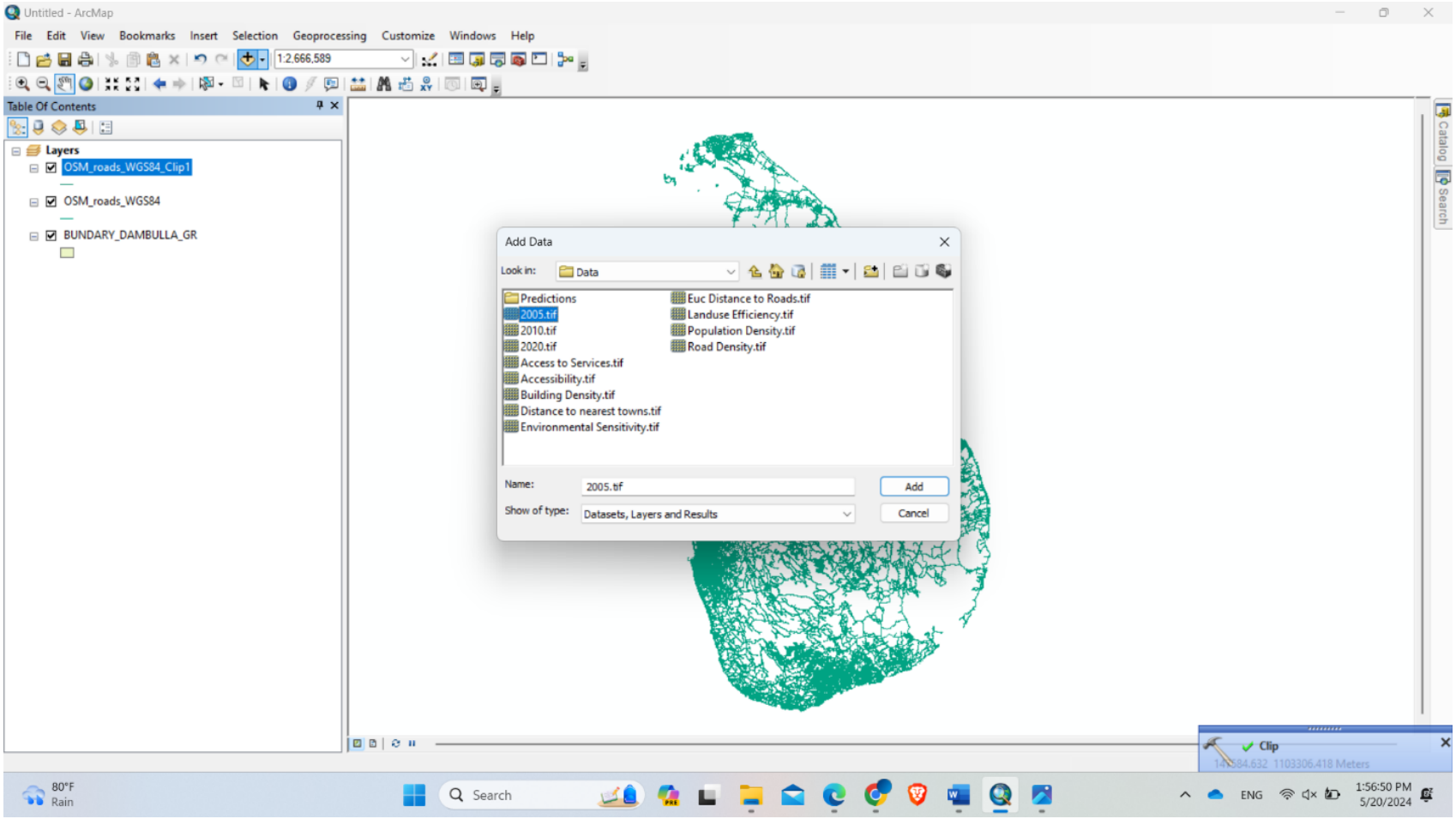


Once the Clip tool has finished running, the new clipped road layer will be added to your map. Review the output to ensure that it accurately represents the roads within the specified boundary area.

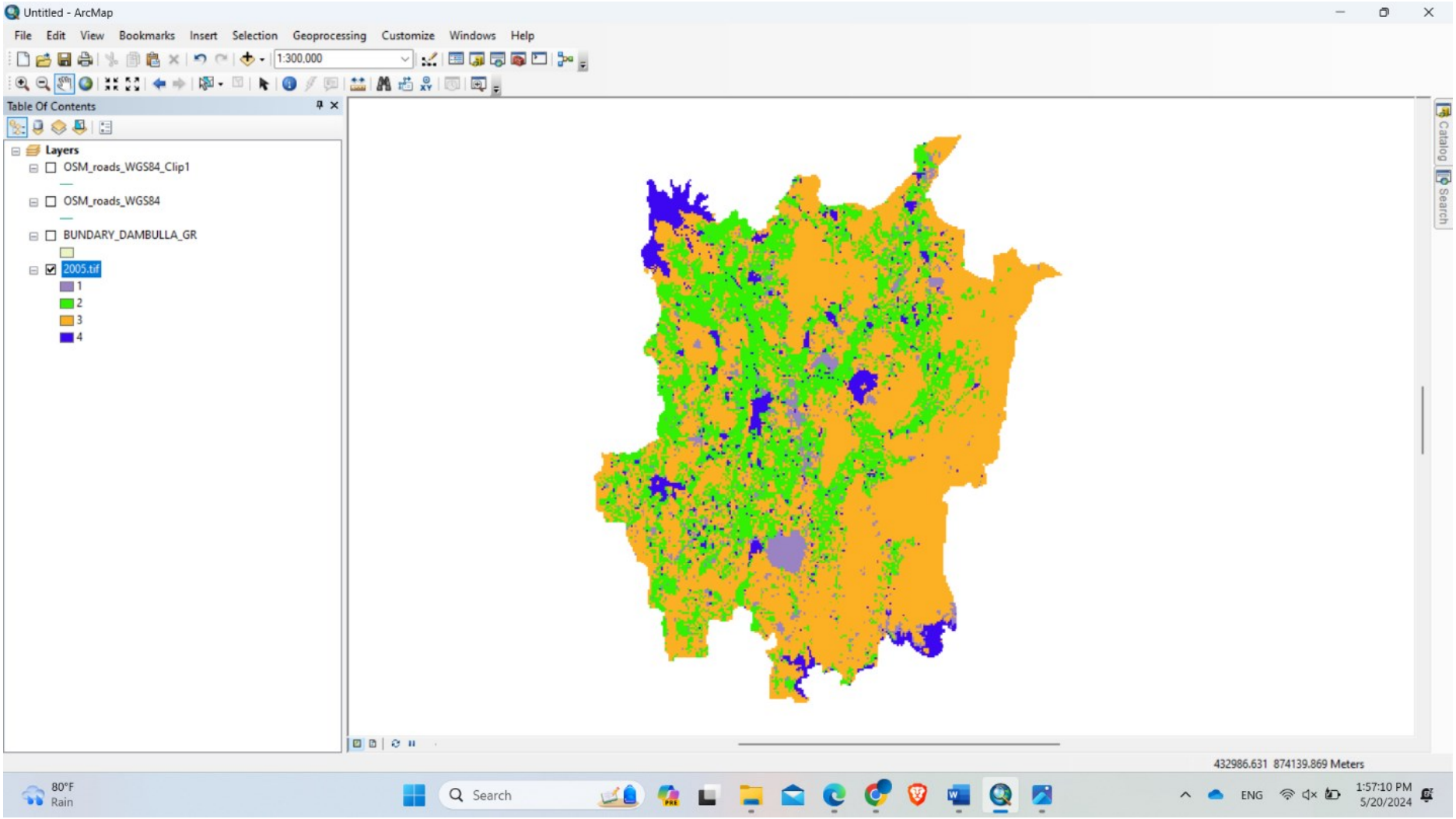


4. Adding a previously prepared correct raster file for the setup of new factors.

We need to ensure that the correct raster file is used because we follow the coordinate system, pixel size, and row and column configuration of this file. For this purpose, I have used a previously prepared 2005 Land use raster file.

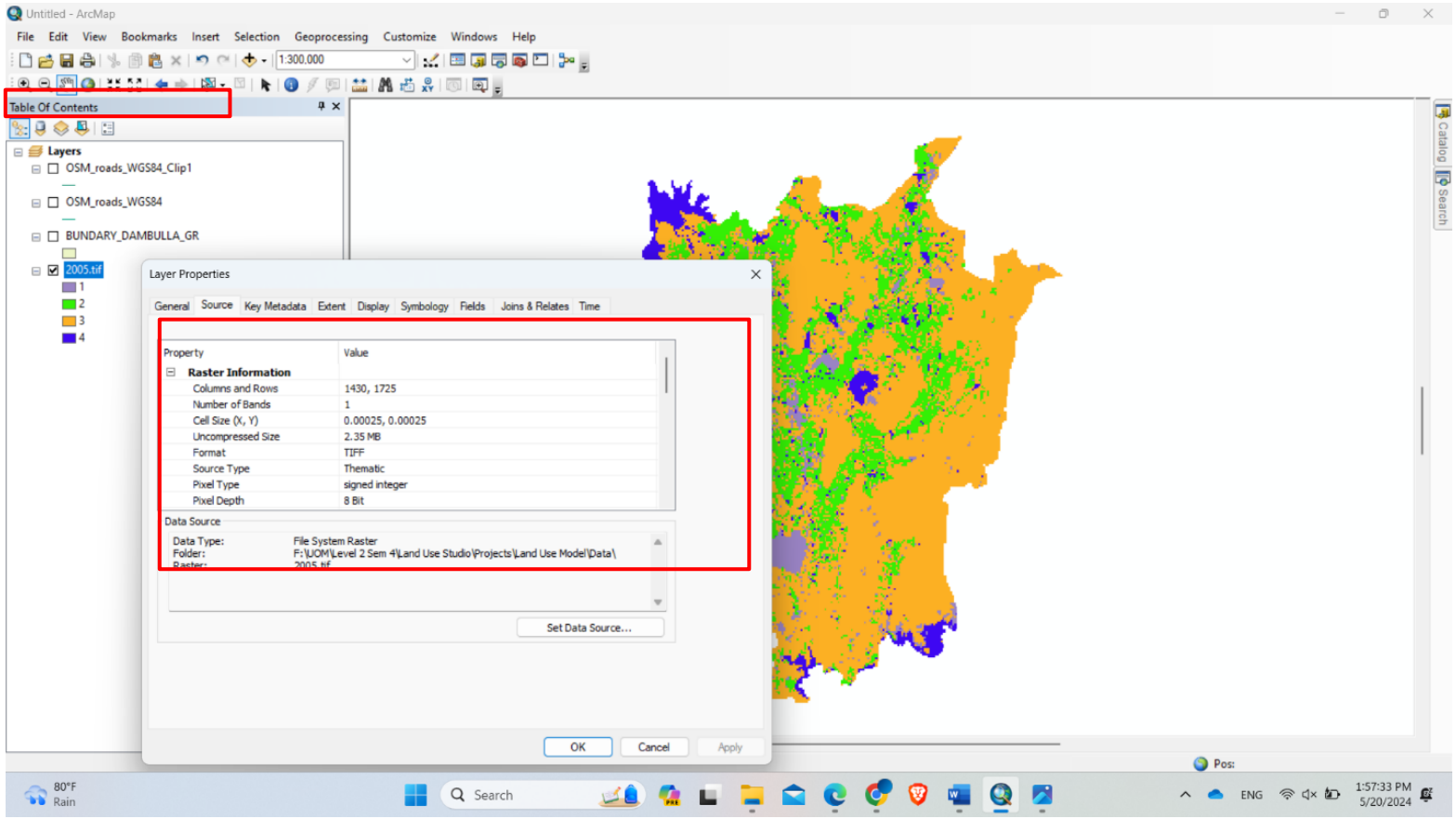


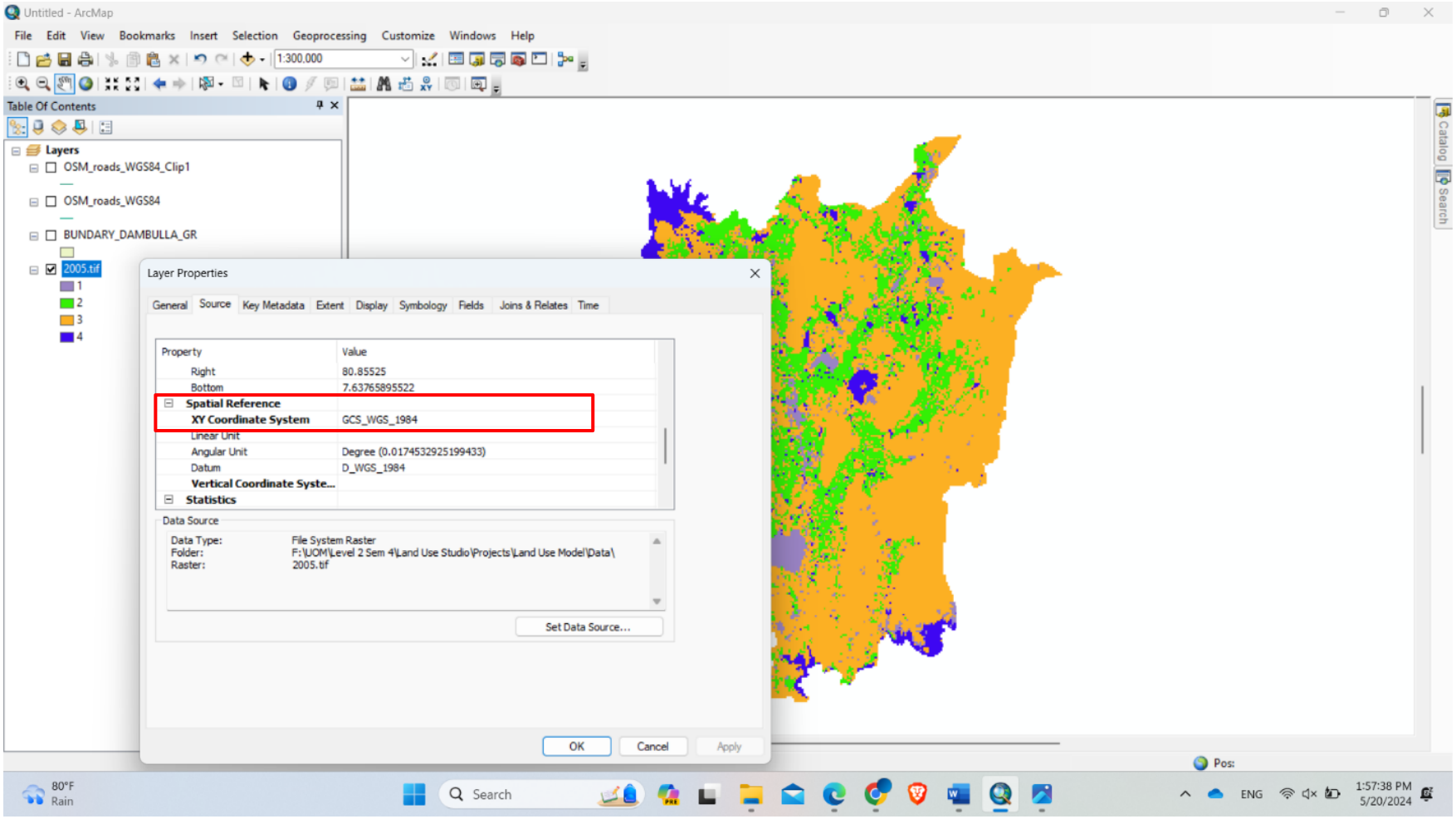
The previously prepared land use layer for the year 2005 will appear on the screen as follows.



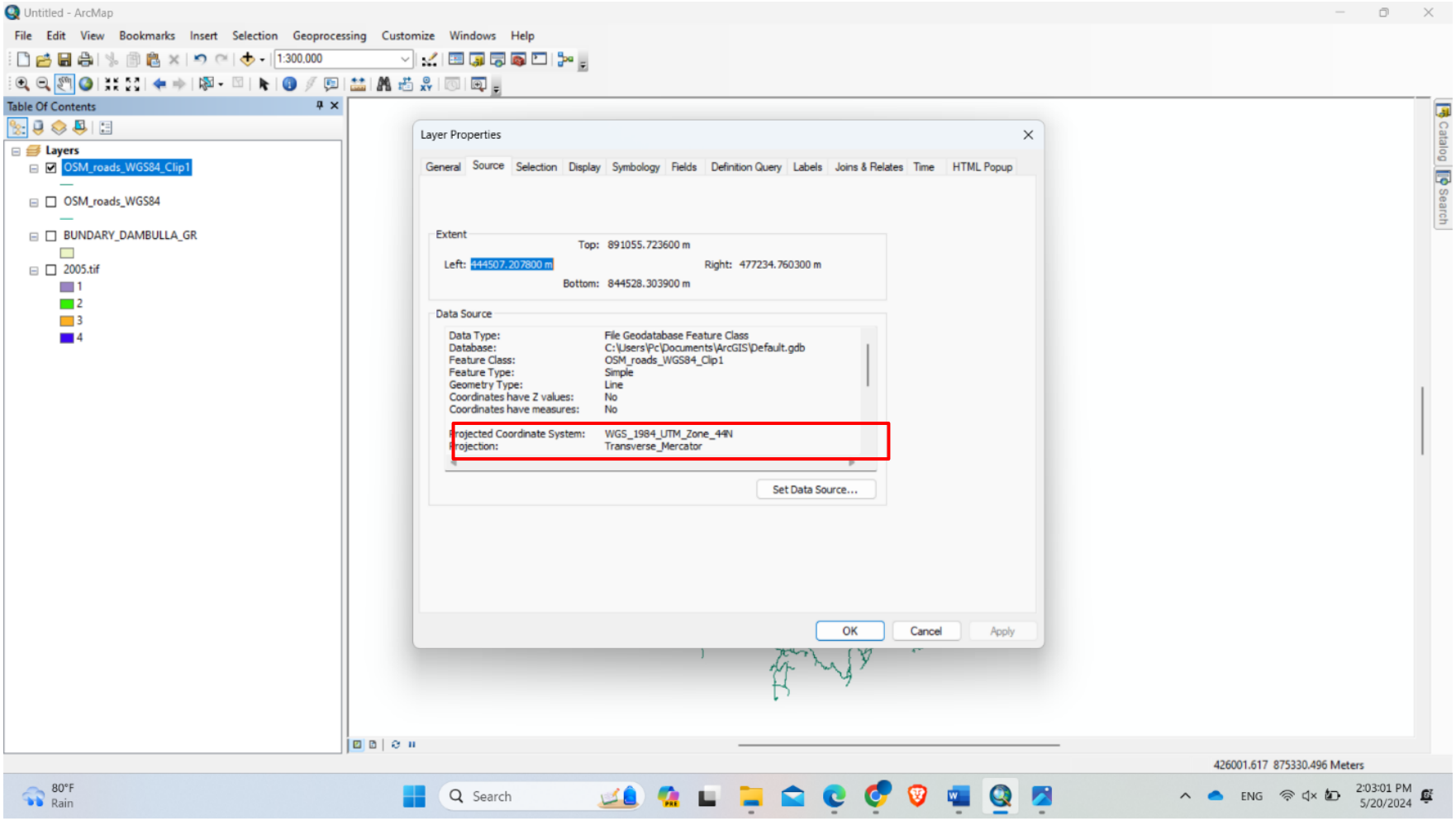
5. Ensure Consistent Coordinate Systems

- First, make sure that all your layers (road layer, boundary shapefile, and raster file) have the same coordinate system.
- Right-click each layer in the Table of Contents, select "**Properties**," then go to the "**Source**" tab to check the coordinate system.
- After that, checked and noted the pixel size and row columns of the 2005 land use raster file.




Untitled - ArcMap
File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
1:300,000
Table Of Contents
Layers
OSM_roads_WGS84_Clip1
OSM_roads_WGS84
BUNDARY_DAMBULLA_GR
2005.tif
1
2
3
4
Layer Properties
General Source Key Metadata Extent Display Symbology Fields Joins & Relates Time
Property Value
Right 80.85525
Bottom 7.63765895522
Spatial Reference
XY Coordinate System GCS_WGS_1984
Linear Unit
Angular Unit Degree (0.0174532925199433)
Datum D_WGS_1984
Vertical Coordinate Syste...
Statistics
Data Source
Data Type: File System Raster
Folder: F:\UOM\Level 2 Sem 4\Land Use Studio\Projects\Land Use Model\Data\
Raster: 2005.tif
Set Data Source...
OK
Cancel
Apply
Catalog
Search
Pos:
80°F Rain
Search
ENG
1:57:38 PM 5/20/2024

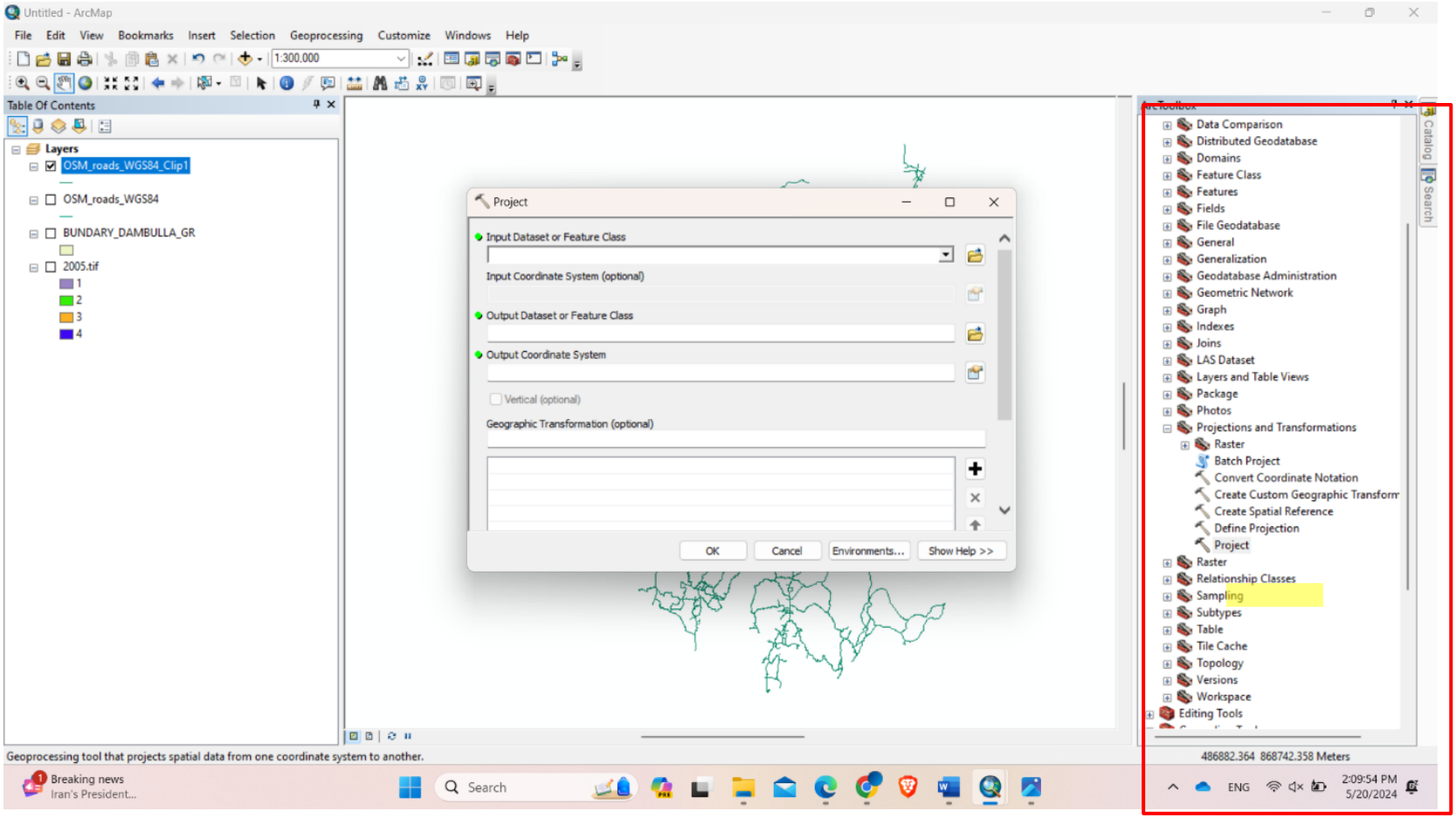
Upon examination, I observed discrepancies in the coordinate system of the clipped file. Consequently, I utilized the "**Project**" tool to rectify the coordinate system of the clipped file to match the desired one.



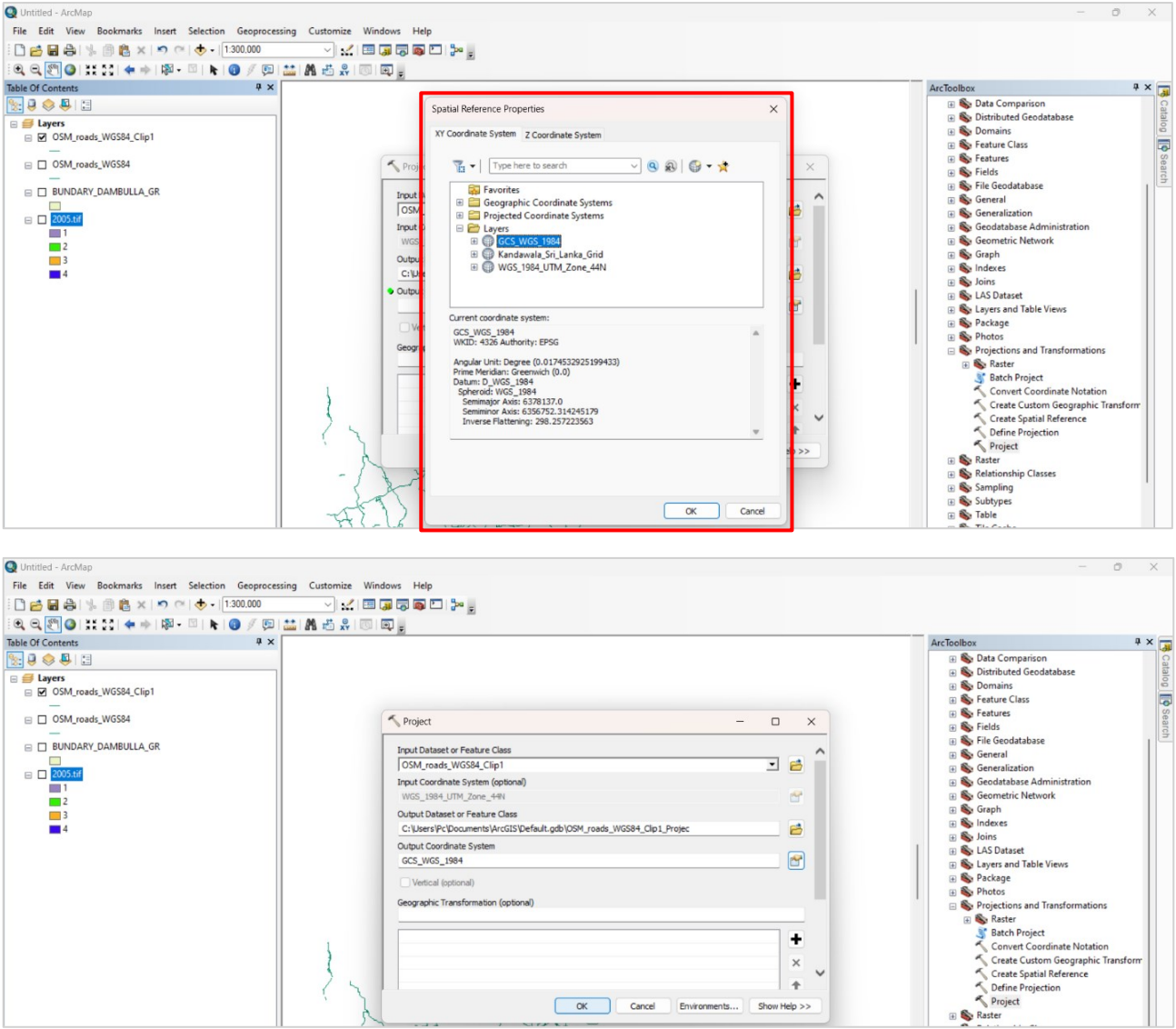
6. Project (.shp) file to the same coordinate system.

If any layers have different coordinate systems, you need to project them to the same coordinate system. You can use the "**Project**" tool found under,

Arc Toolbox > Data Management Tools > Projections and Transformations > Project



Select the Clipped Road layer to the Input Dataset or feature class and select 2005 Land use raster layers' coordinate system to coordinate system.


Untitled - ArcMap
File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
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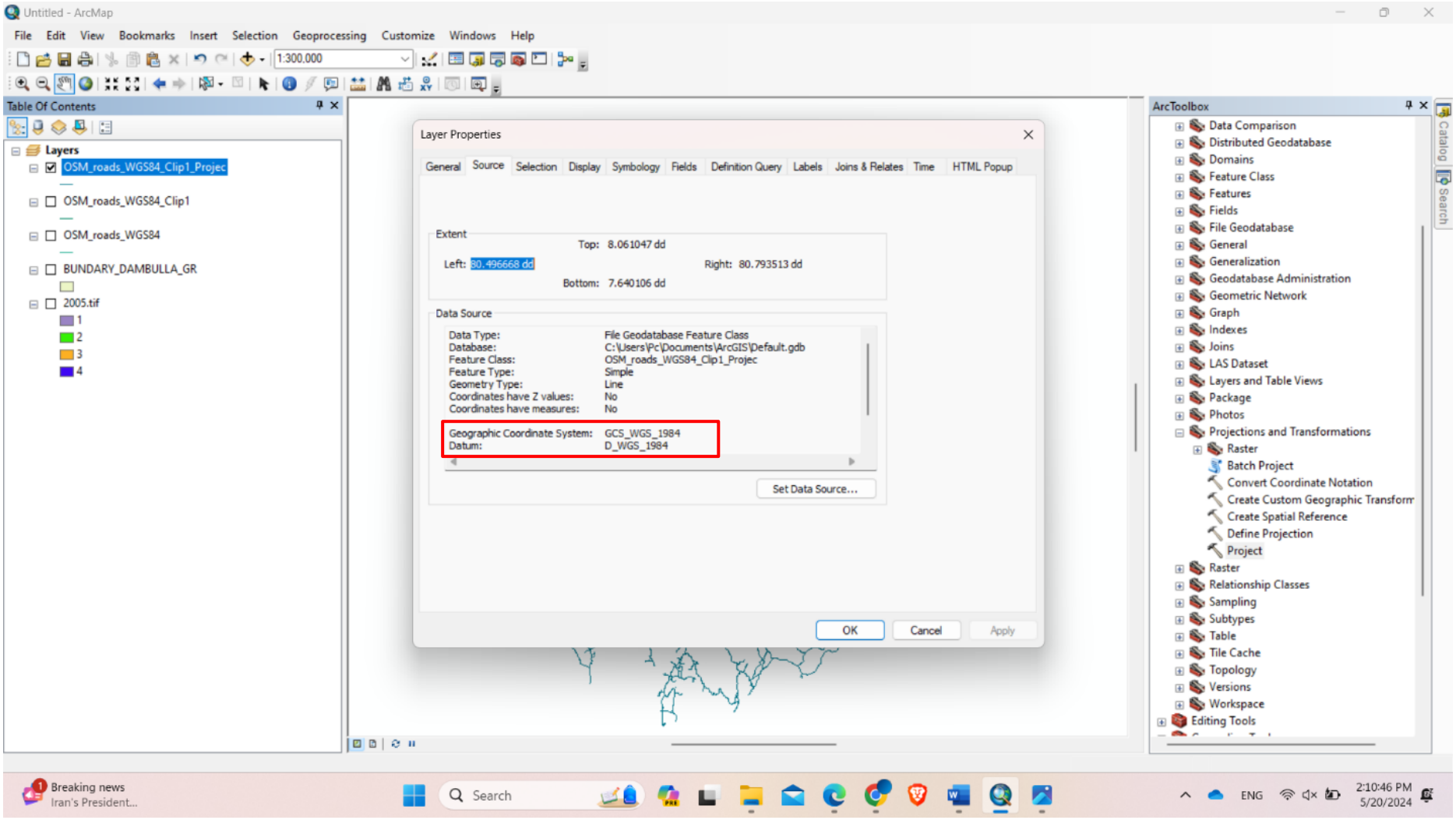
Layers
OSM_roads_WGS84_Clip1
OSM_roads_WGS84
BUNDARY_DAMBULLA_GR
2005.tif
1
2
3
4
Spatial Reference Properties
XY Coordinate System
Z Coordinate System
Type here to search
Favorites
Geographic Coordinate Systems
Projected Coordinate Systems
Layers
GCS_WGS_1984
Kandawala_Sri_Lanka_Grid
WGS_1984_UTM_Zone_44N
Current coordinate system:
GCS_WGS_1984
WKID: 4326 Authority: EPSG
Angular Unit: Degree (0.0174532925199433)
Prime Meridian: Greenwich (0.0)
Datum: D_WGS_1984
Spheroid: WGS_1984
Semimajor Axis: 6378137.0
Seminminor Axis: 6356752.314245179
Inverse Flattening: 298.257223563
OK
Cancel
ArcToolbox
Data Comparison
Distributed Geodatabase
Domains
Feature Class
Features
Fields
File Geodatabase
General
Generalization
Geodatabase Administration
Geometric Network
Graph
Indexes
Joins
LAS Dataset
Layers and Table Views
Package
Photos
Projections and Transformations
Raster
Batch Project
Convert Coordinate Notation
Create Custom Geographic Transform
Create Spatial Reference
Define Projection
Project
Relationship Classes
Sampling
Subtypes
Table
Catalog
Search

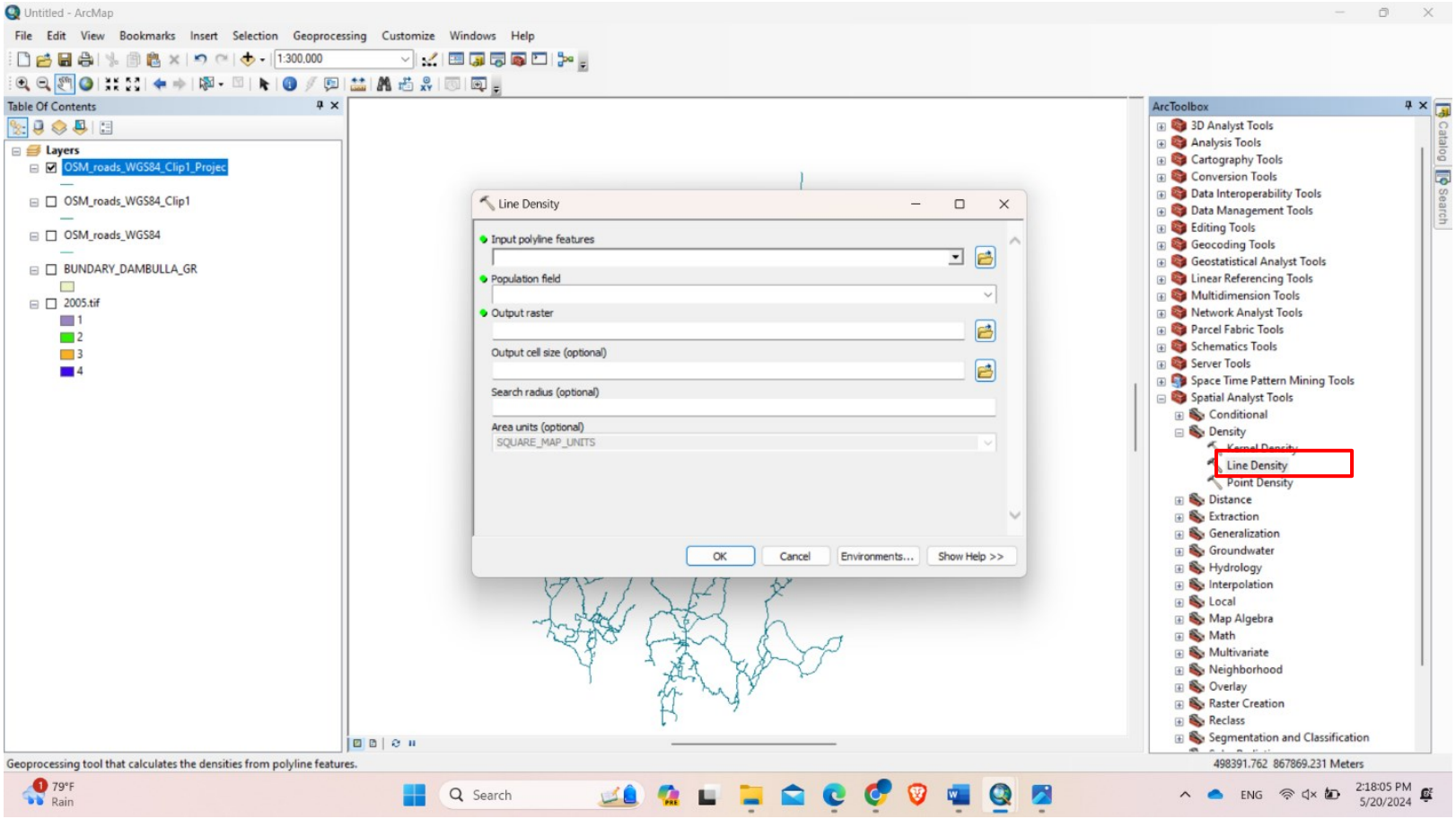
Untitled - ArcMap
File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
Table Of Contents
Layers
OSM_roads_WGS84_Clip1
OSM_roads_WGS84
BUNDARY_DAMBULLA_GR
2005.tif
1
2
3
4
Project
Input Dataset or Feature Class
OSM_roads_WGS84_Clip1
Input Coordinate System (optional)
WGS_1984_UTM_Zone_44N
Output Dataset or Feature Class
C:\Users\Pc\Documents\ArcGIS\Default.gdb\OSM_roads_WGS84_Clip1_Projec
Output Coordinate System
GCS_WGS_1984
Vertical (optional)
Geographic Transformation (optional)
OK
Cancel
Environments...
Show Help >>
ArcToolbox
Data Comparison
Distributed Geodatabase
Domains
Feature Class
Features
Fields
File Geodatabase
General
Generalization
Geodatabase Administration
Geometric Network
Graph
Indexes
Joins
LAS Dataset
Layers and Table Views
Package
Photos
Projections and Transformations
Raster
Batch Project
Convert Coordinate Notation
Create Custom Geographic Transform
Create Spatial Reference
Define Projection
Project
Catalog
Search

Once the project tool has finished running, check the coordinate system of the raster file.



7. **Open the Line Density Tool.**

- Go to "**ArcToolbox**" and navigate to **Spatial Analyst Tools > Density > Line Density**.
- If "Spatial Analyst" is not enabled, you need to activate it by going to **Customize > Extensions** and checking "Spatial Analyst".

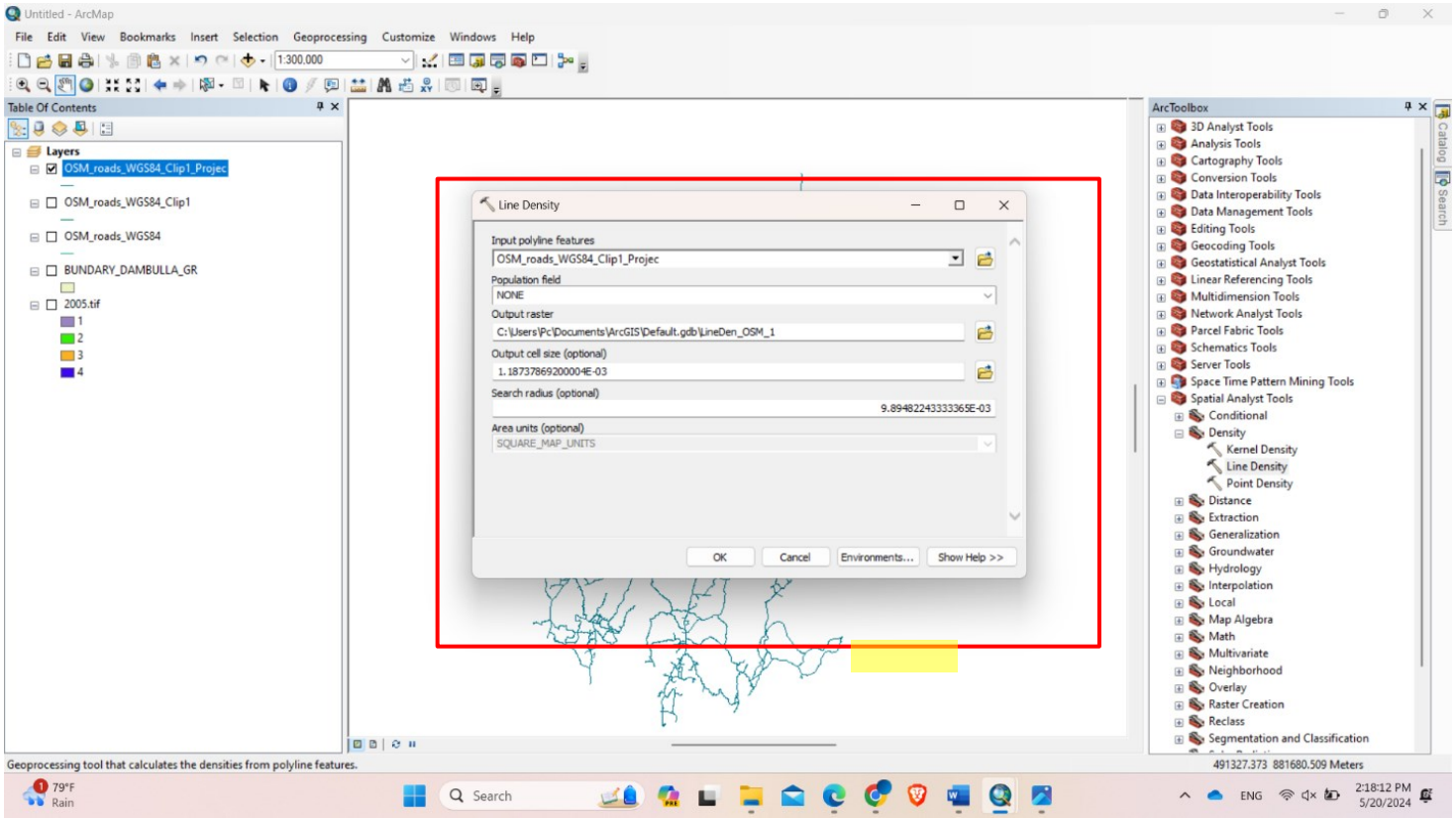


Set Line Density Tool Parameters

In the Line Density tool dialog box, set the following parameters:

I. **Input Polyline Features:** Select your correct road layer.

II. **Output Raster:** Specify the location and name for the output raster file.



Adjusting Pixel Size and Aligning with Existing Raster

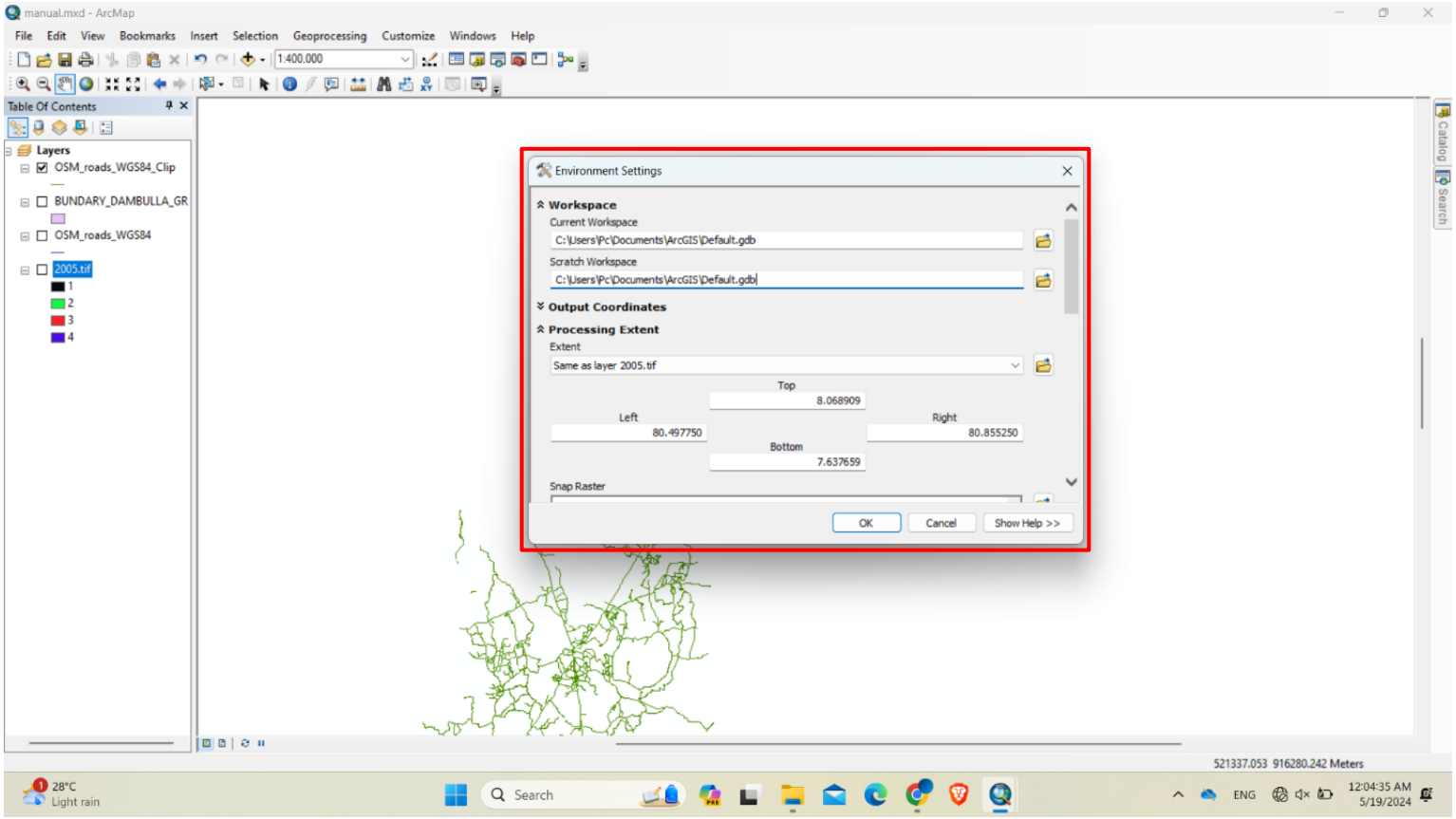
I. If the output raster needs to match an existing raster's pixel size and alignment exactly, use the environment setting. Go to Environments.

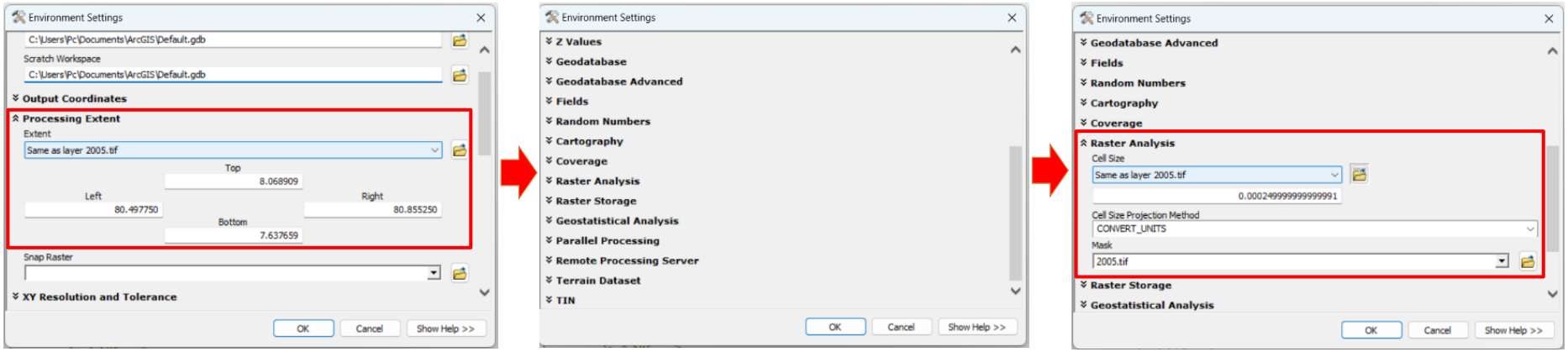
II. Then set up the workspace as the default workspace.

III. Under "**Raster Analysis**," set the "**Cell Size**" to match your existing raster and set the " **Mask**" to match your existing raster.

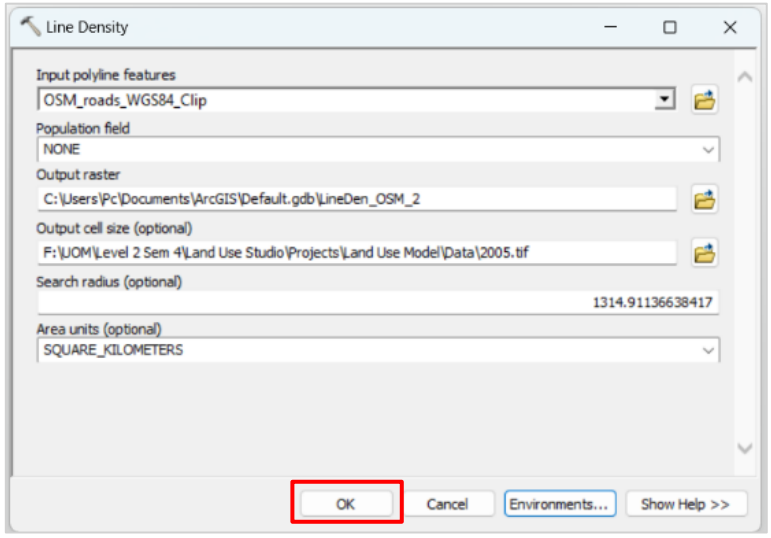
IV. Under "**Processing Extent**," set the "**Extent**" to your existing raster layer.

Then change the environment setting as follows.

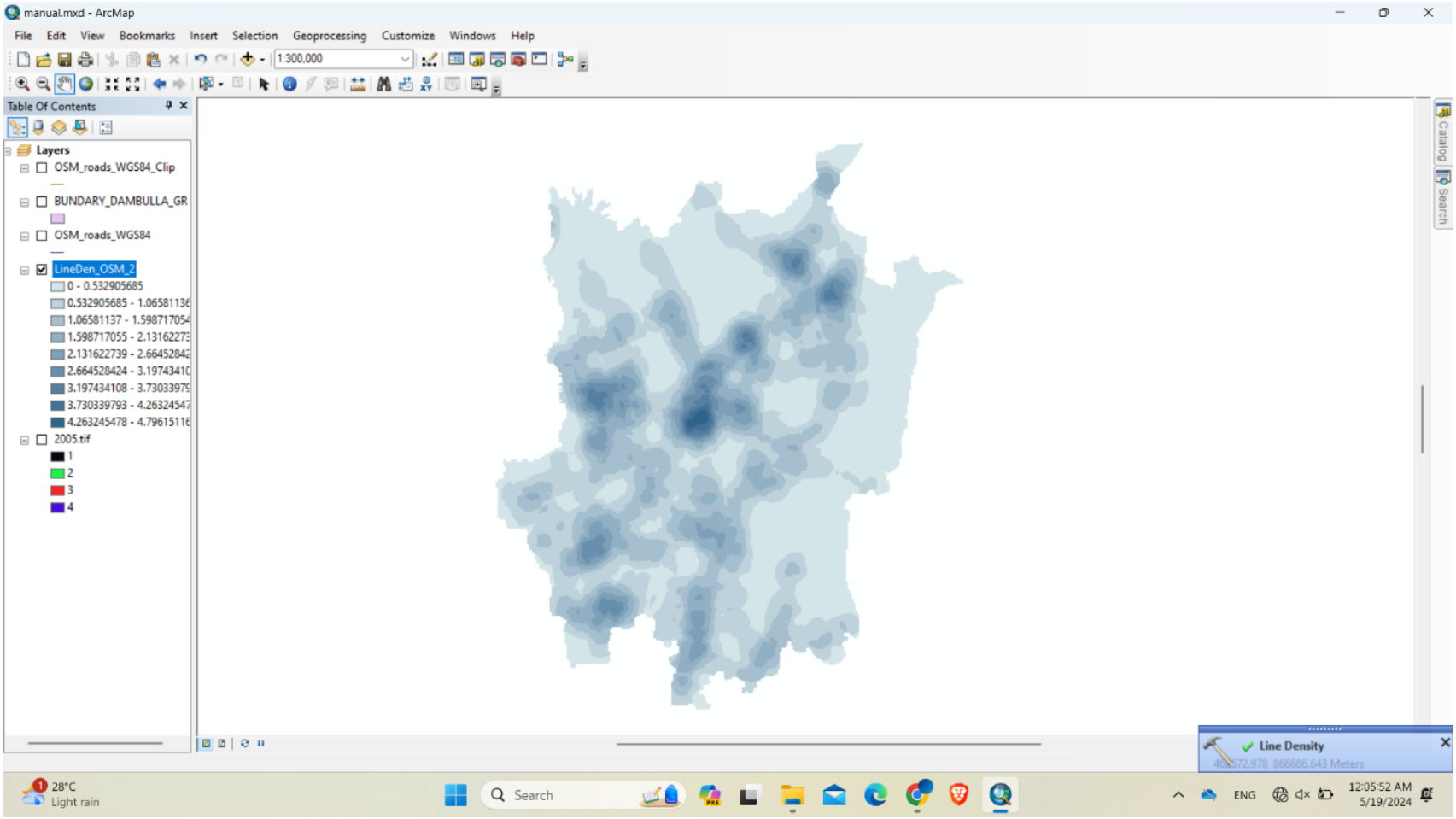




Then click "**OK**" to come back to the line density tool as follows. Again click on "**OK**" to run the tool.



Once the Line Density tool has finished running, the new road density raster will be added to your map. Review the output to ensure it accurately represents road density.



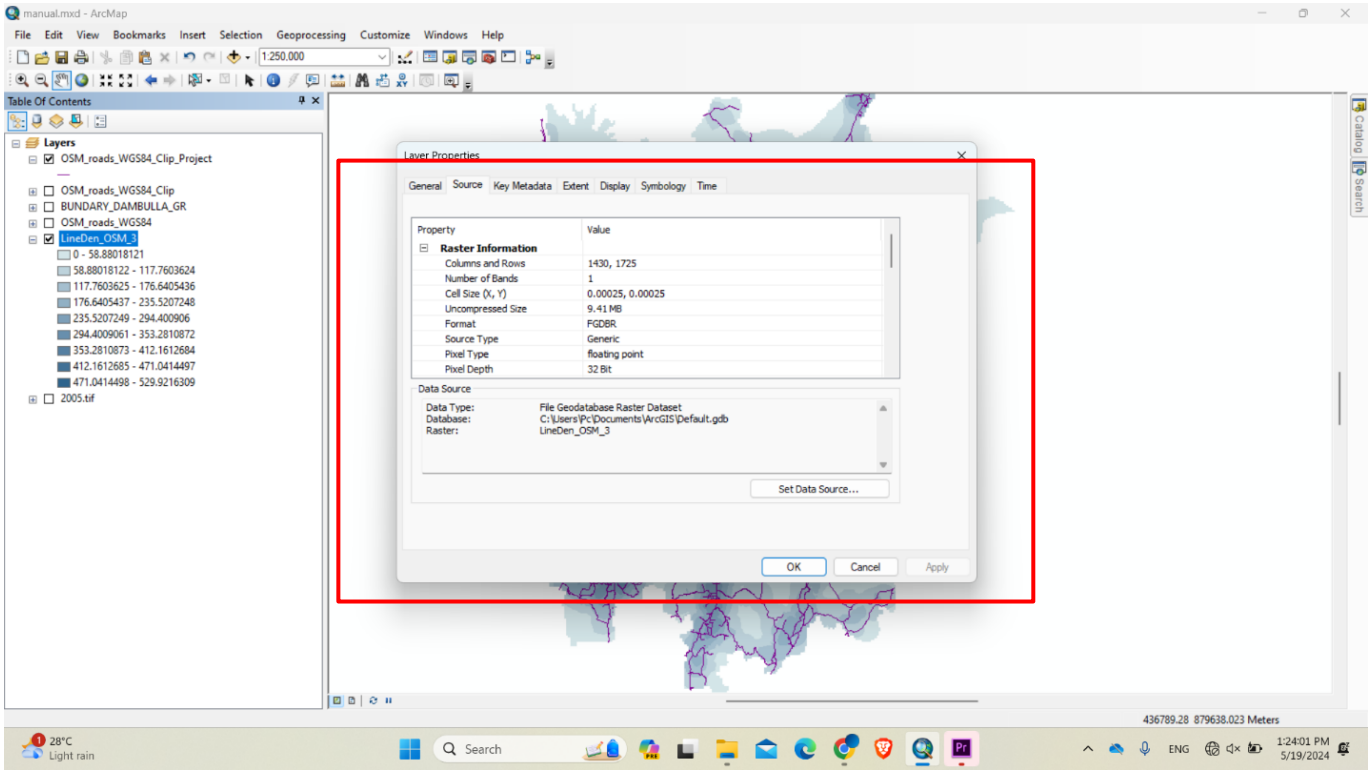
8. Check the coordinate system, pixel size, and rows & columns

I. Right-click on the layer in the Table of Contents.

II. Select "**Properties**".

III. In the Layer Properties dialog box, go to the "**Source**" tab.

The coordinate system information will be displayed in this tab. Ensure that it matches the desired coordinate system for your project.

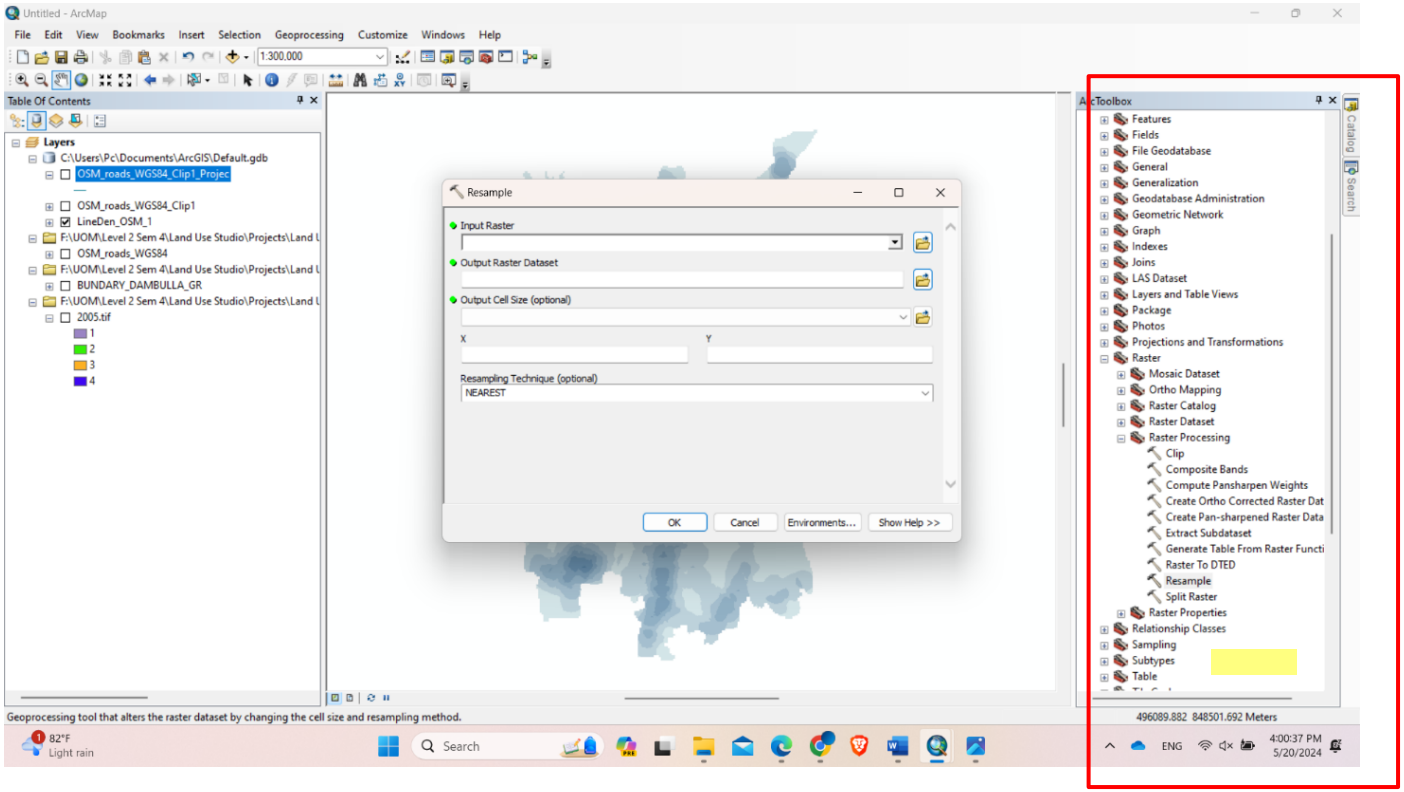


9. **Resample a Raster File.**

If you notice that the raster file does not have the correct pixel size or number of rows and columns, you can resample it. (The first result obtained here is the same as the 2005 raster file values, so there is no need for a resample.)

Open the Resample Tool

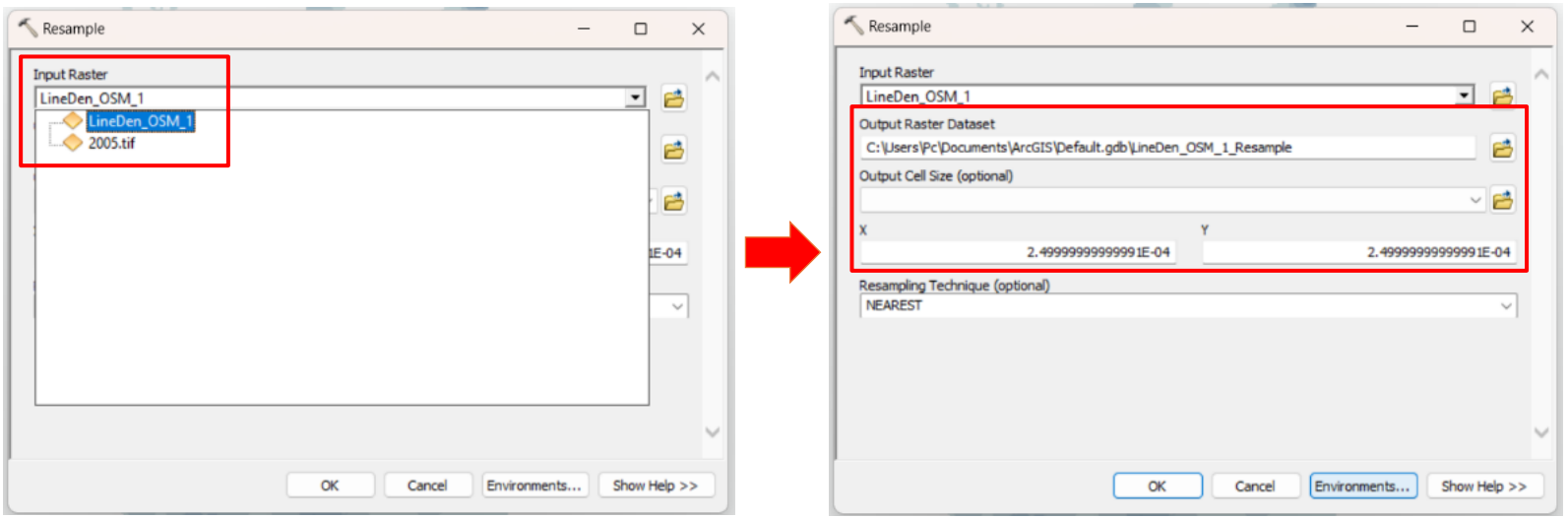
Go to "**ArcToolbox**" and navigate to **Data Management Tools > Raster > Raster Processing > Resample**



Set Resample Tool Parameters

In the Resample dialog box, set the following parameters:

I. **Input Raster:** Select the raster file that needs resampling.
II. **Output Raster Dataset:** Specify the location and name for the resampled raster file.
III. **Output Cell Size:** Enter the desired cell size for the resampled raster. This should match the pixel size you need.



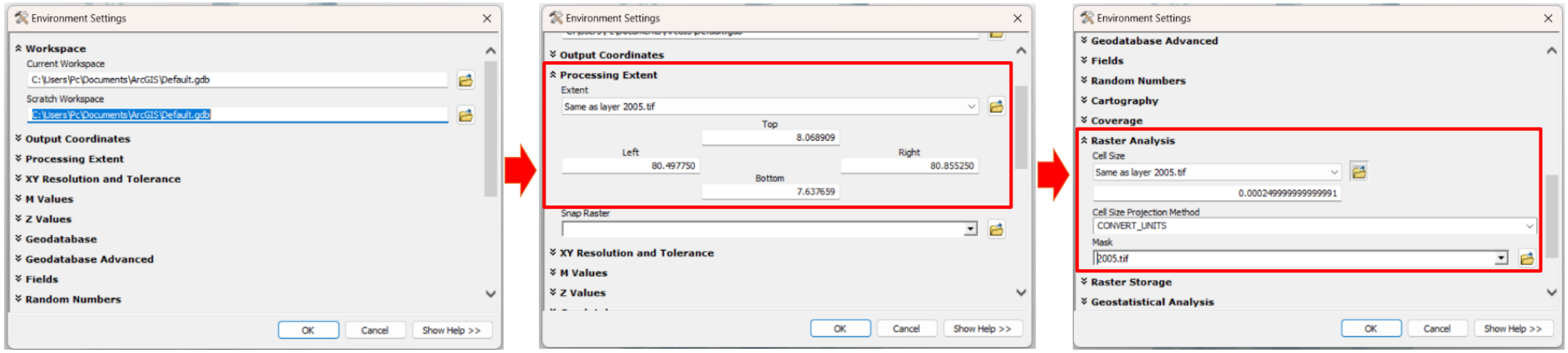
Change Environment Settings

Go to the "**Environments**".

In the Environment Settings dialog box, set the following:

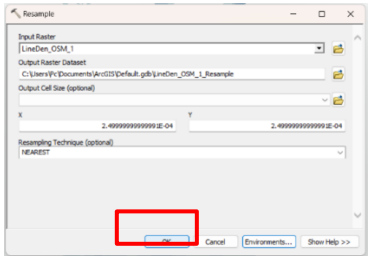
I. If the output raster needs to match an existing raster's pixel size and alignment exactly, use the environment setting. Go to Environments.
II. Then set up the workspace as the default workspace.
III. Under "**Raster Analysis**," set the "**Cell Size**" to match your existing raster and set the " **Mask**" to match your existing raster.
IV. Under "**Processing Extent**," set the "**Extent**" to your existing raster layer.

- **Cell Size:** Set this to match the cell size of your resampled raster.
- **Mask:** Optionally, you can set a mask to limit processing to a specific area.

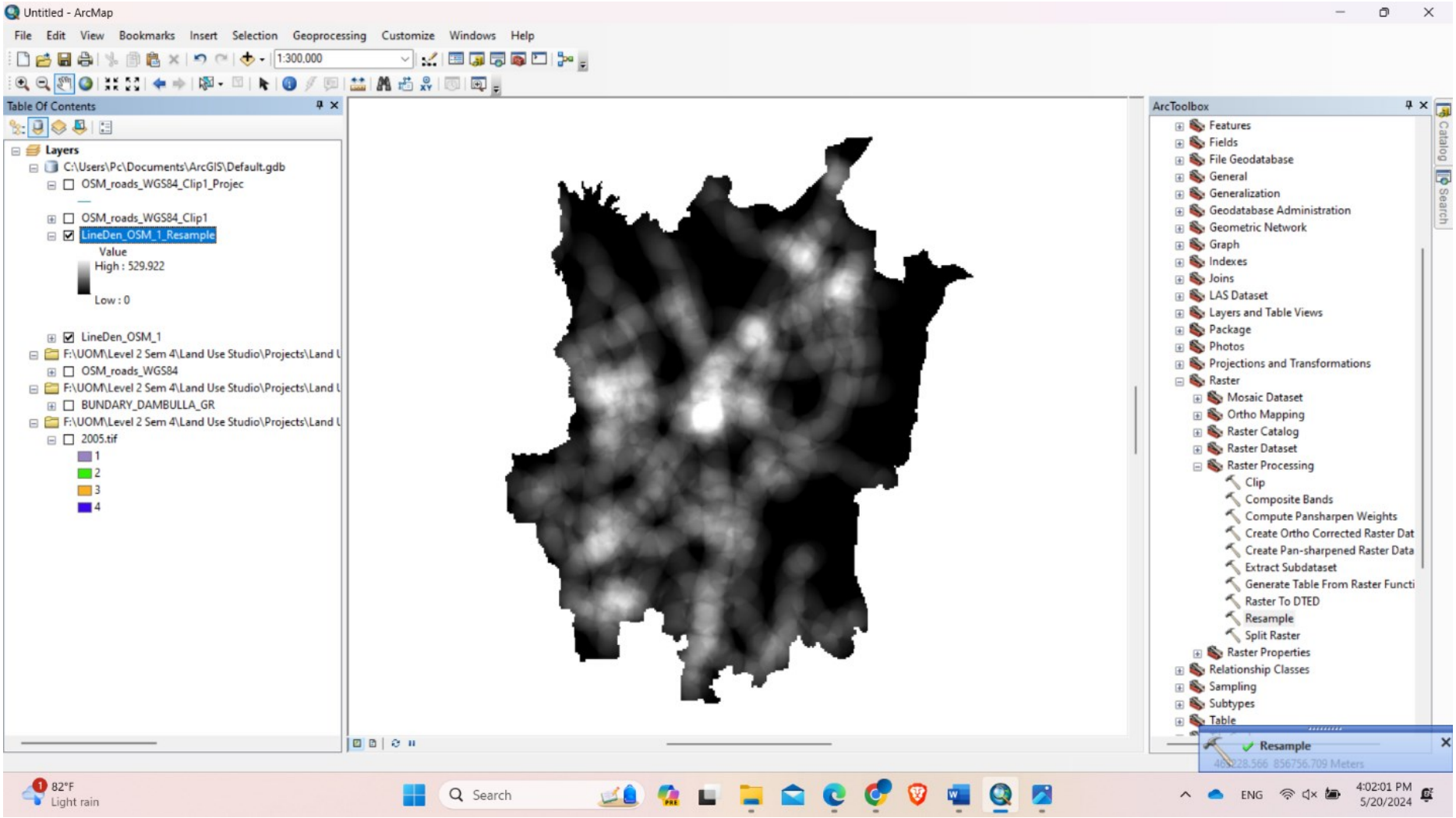


Run the Resample Tool

Click "**OK**" to run the Resample tool. The tool will process the data and create a new raster with the specified cell size.



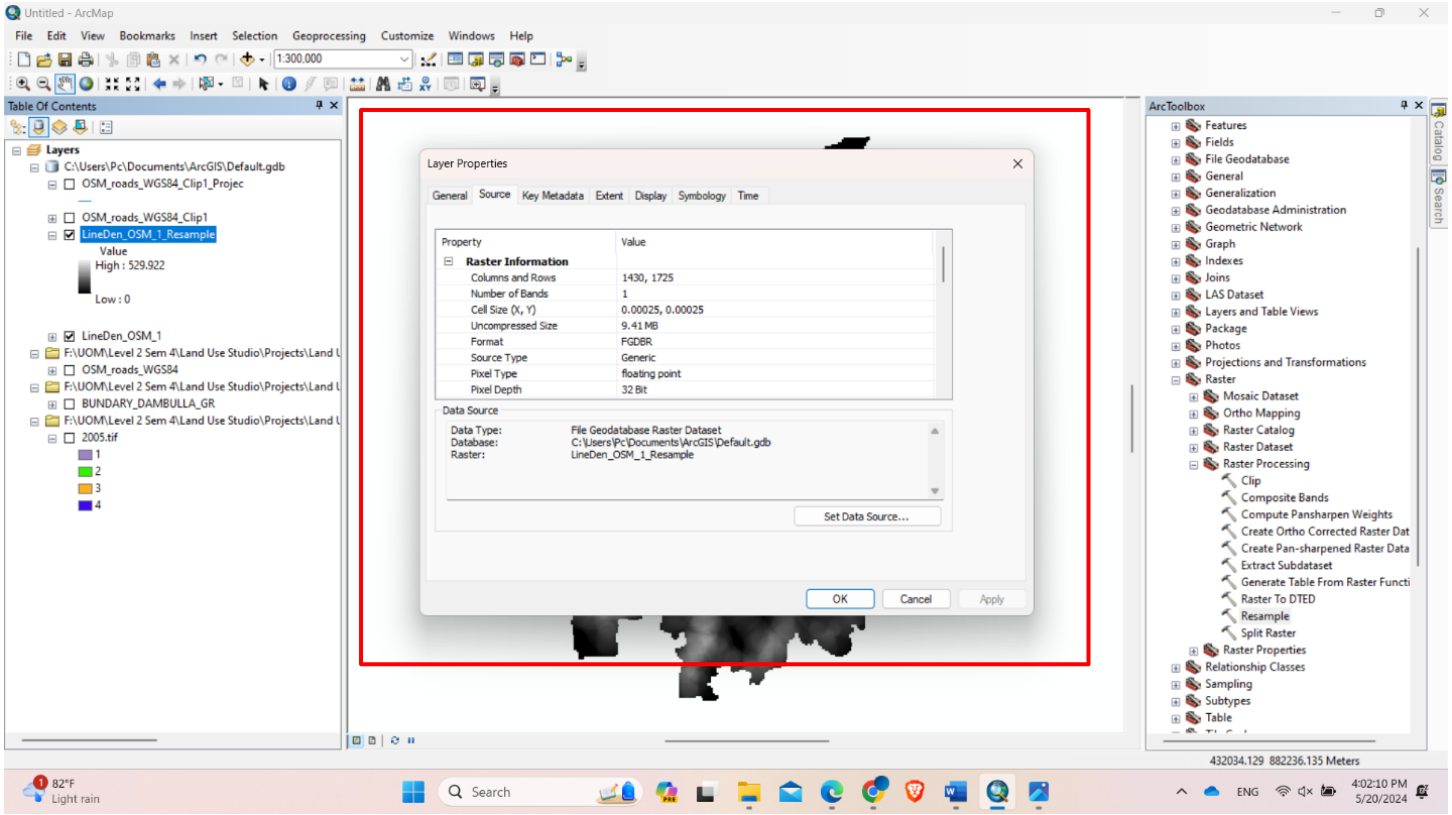
After that, you can see the resampled layer as follows.



Again, check pixel size and rows columns.

- Right-click on the layer in the Table of Contents.

- Select "**Properties**".
- In the Layer Properties dialog box, go to the "**Raster Information**" tab.



- If it is not the same this time, resample it again and then export this layer.

10. Export Layer

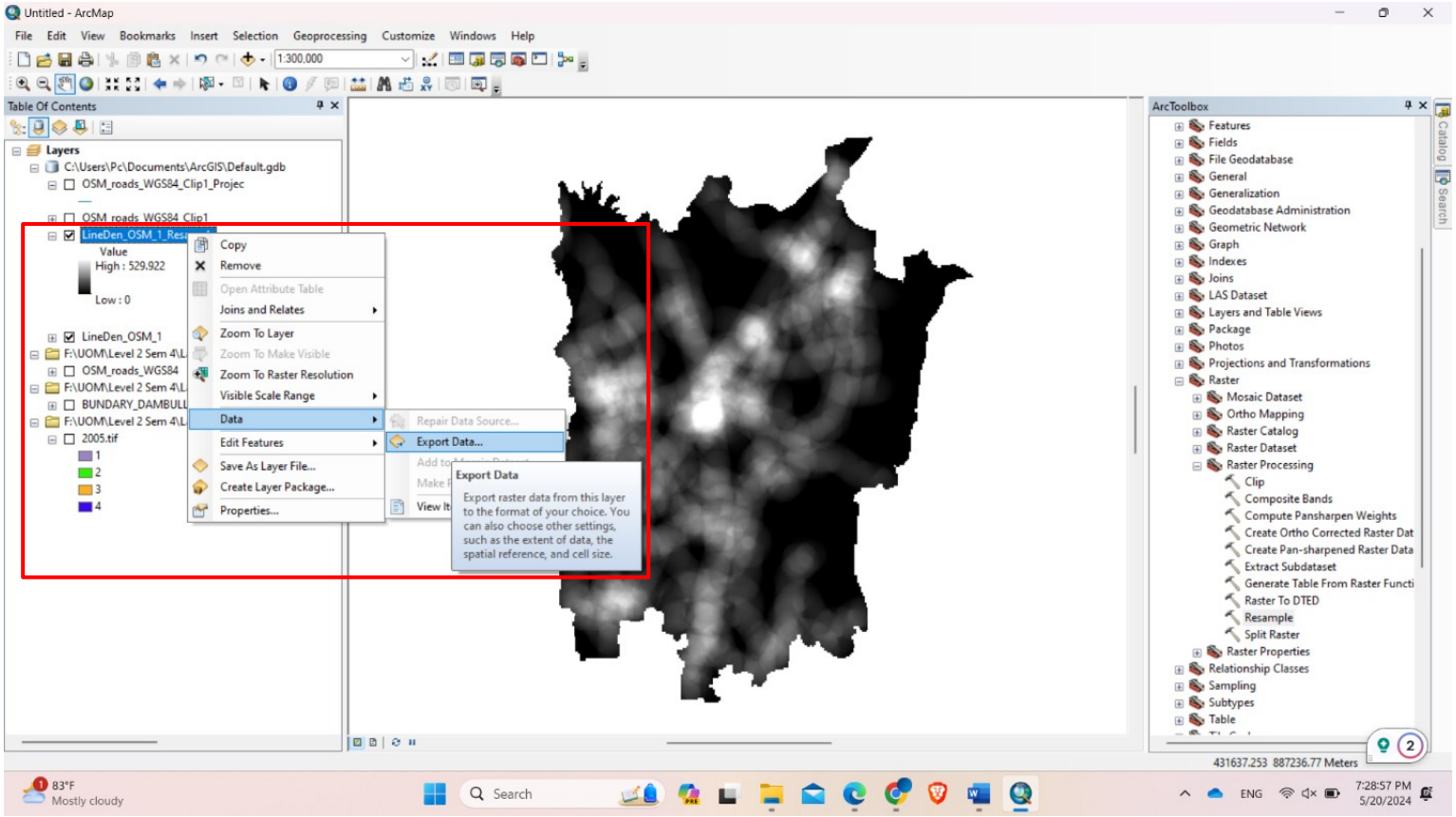
I. Right-click on the layer you want to export in the Table of Contents.

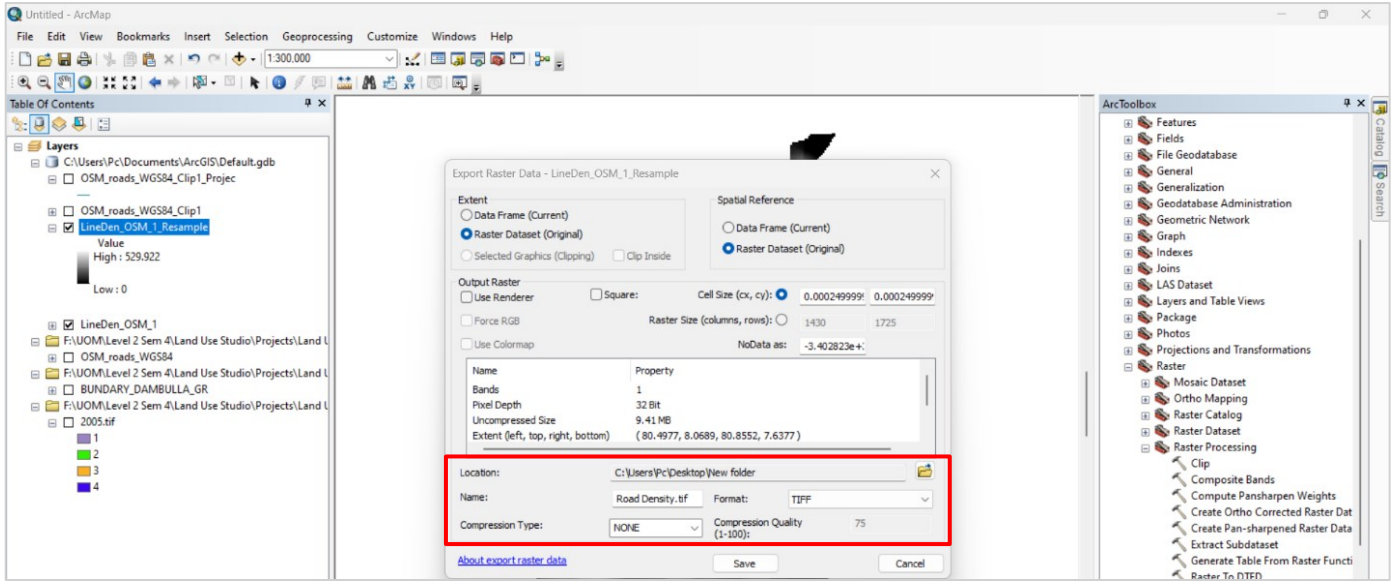
II. Select "**Data**" and then "**Export Data**".

III. In the Export Data dialog box, specify the location and file format for the exported layer.

Optionally, you can select the extent and coordinate system for the exported data.

Click "**OK**" to export the layer with the specified settings.




Untitled - ArcMap
File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
Table Of Contents
Layers
C:\Users\Pc\Documents\ArcGIS\Default.gdb
OSM_roads_WGS84_Clip1_Projec
OSM_roads_WGS84_Clip1
LineDen_OSM_1_Resample
Value
High : 529.922
Low : 0
LineDen_OSM_1
F:\UOM\Level 2 Sem 4\Land Use Studio\Projects\Land U
OSM_roads_WGS84
BUNDARY_DAMBULLA_GR
2005.tif
1
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3
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Export Raster Data - LineDen_OSM_1_Resample
Extent
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Raster Dataset (Original)
Selected Graphics (Clipping)
Clip Inside
Spatial Reference
Output Raster
Use Renderer
Square:
Cell Size (cx, cy):
Force RGB
Raster Size (columns, rows):
1430
1725
Use Colormap
NoData as:
Name
Property
Bands
1
Pixel Depth
32 Bit
Uncompressed Size
9.41 MB
Extent (left, top, right, bottom)
(80.4977, 8.0689, 80.8552, 7.6377)
Location:
C:\Users\Pc\Desktop\New folder
Name:
Road Density.tif
Format:
TIFF
Compression Type:
NONE
Compression Quality (1-100):
75
About export raster data
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Cancel
ArcToolbox
Features
Fields
File Geodatabase
General
Generalization
Geodatabase Administration
Geometric Network
Graph
Indexes
Joins
LAS Dataset
Layers and Table Views
Package
Photos
Projections and Transformations
Raster
Mosaic Dataset
Ortho Mapping
Raster Catalog
Raster Dataset
Raster Processing
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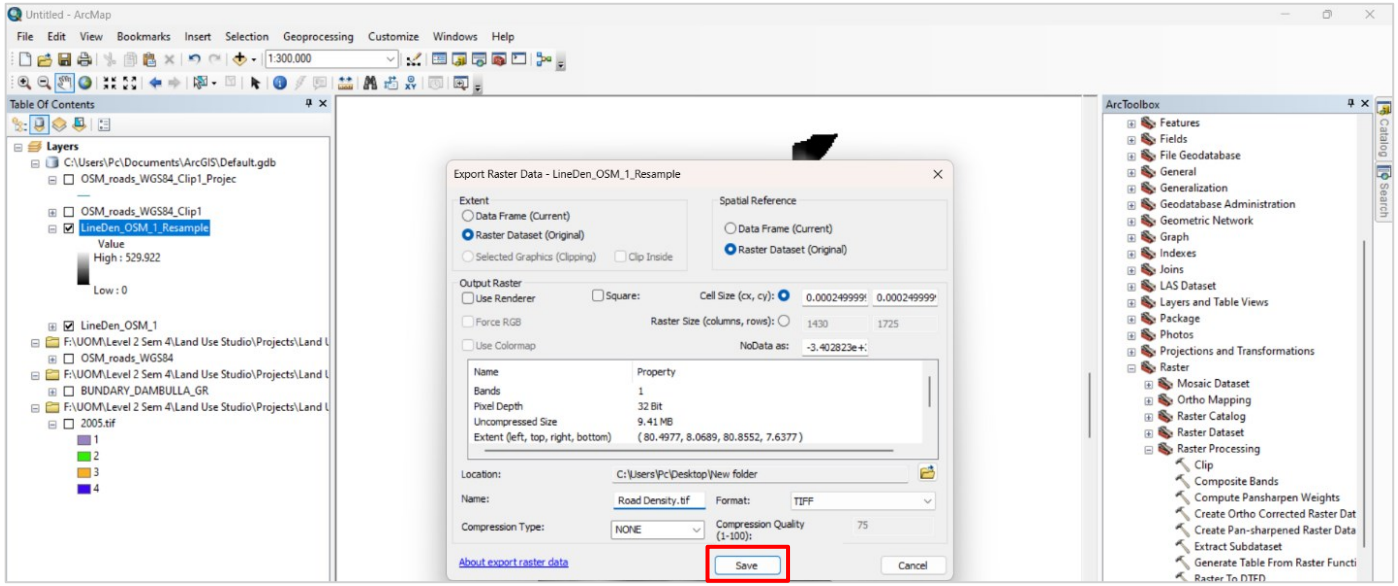
Create Pan-sharpened Raster Data
Extract Subdataset
Generate Table From Raster Functi
Catalog
Search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File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
Table Of Contents
Layers
C:\Users\Pc\Documents\ArcGIS\Default.gdb
OSM_roads_WGS84_Clip1_Projec
OSM_roads_WGS84_Clip1
LineDen_OSM_1_Resample
Value
High : 529.922
Low : 0
LineDen_OSM_1
F:\UOM\Level 2 Sem 4\Land Use Studio\Projects\Land U
OSM_roads_WGS84
BUNDARY_DAMBULLA_GR
2005.tif
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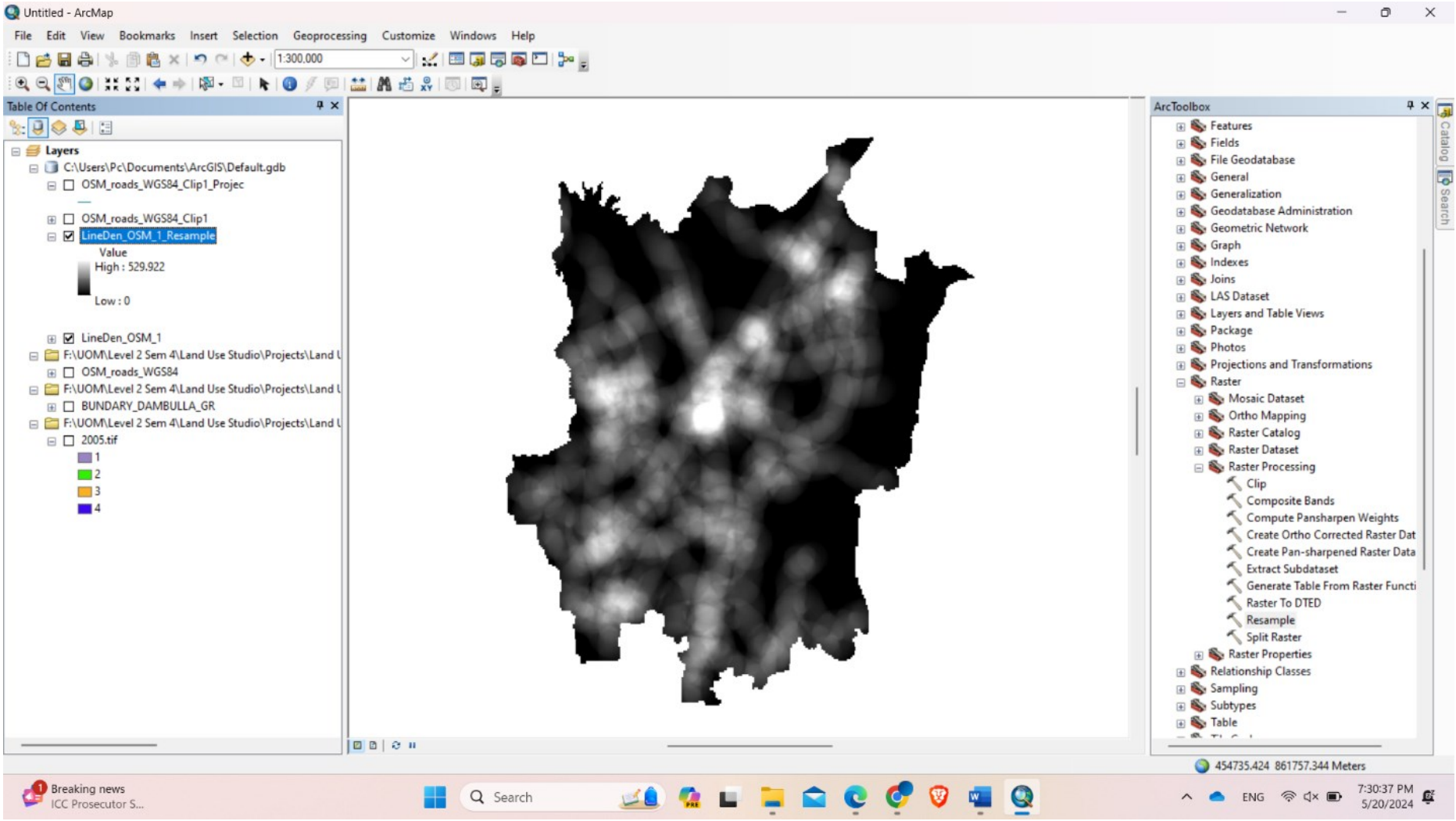
Export Raster Data - LineDen_OSM_1_Resample
Extent
Data Frame (Current)
Raster Dataset (Original)
Selected Graphics (Clipping)
Clip Inside
Spatial Reference
Output Raster
Use Renderer
Square:
Cell Size (cx, cy):
Force RGB
Raster Size (columns, rows):
1430
1725
Use Colormap
NoData as:
Name
Property
Bands
1
Pixel Depth
32 Bit
Uncompressed Size
9.41 MB
Extent (left, top, right, bottom)
(80.4977, 8.0689, 80.8552, 7.6377)
Location:
C:\Users\Pc\Desktop\New folder
Name:
Road Density.tif
Format:
TIFF
Compression Type:
NONE
Compression Quality (1-100):
75
About export raster data
Save
Cancel
ArcToolbox
Features
Fields
File Geodatabase
General
Generalization
Geodatabase Administration
Geometric Network
Graph
Indexes
Joins
LAS Dataset
Layers and Table Views
Package
Photos
Projections and Transformations
Raster
Mosaic Dataset
Ortho Mapping
Raster Catalog
Raster Dataset
Raster Processing
Clip
Composite Bands
Compute Pansharpen Weights
Create Ortho Corrected Raster Dat
Create Pan-sharpened Raster Data
Extract Subdataset
Generate Table From Raster Functi
Catalog
Search

Now that we have created and verified the road density raster layer, we can use it as a key input for the MOLUSCE (Module for Land Use Change Evaluation) land use prediction model.



3. Euclidean distances between roads

Considering the Euclidean distance between roads as a factor in land use prediction is crucial for several reasons. Firstly, accessibility and connectivity are significantly impacted by the proximity to roads. Areas closer to roads generally have better access to transportation networks, making them more attractive for residential, commercial, and industrial developments. This improved accessibility often leads to the development of infrastructure and services, further enhancing the appeal of these areas for various land uses.

Economic development is another key reason for considering Euclidean distance between roads. The distance to roads directly affects transportation costs for businesses, with shorter distances typically resulting in lower costs. This can influence business location decisions and promote economic activities in well-connected areas.

In terms of urban planning and expansion, the Euclidean distance to roads is an essential factor in land use allocation. Urban planners use road proximity to ensure that residential areas are close to necessary amenities and that commercial zones have adequate transportation access. This helps in predicting urban sprawl patterns, as areas near existing roads are more likely to be developed, shaping the overall growth and development of urban regions.

To prepare the Euclidean distance for the road layer, follow the same steps as preparing the road density factor, up to clipping the road layer and ensuring the coordinate system is correct.

1. **Prepare the Road Layer**

- **Download and Add Road Layer**: Download the road layer for Sri Lanka from OpenStreetMap and add it to ArcMap.

  OpenStreetMap: https://www.openstreetmap.org/#map=7/7.879/80.767

  How to download GIS shapefile data from OSM: https://www.youtube.com/watch?v=iA2AF4f1_g4

- **Clip Road Layer**: Use the Clip tool to restrict the road layer to the relevant area using a boundary shapefile.
- **Check Coordinate System**: Verify the coordinate system of the clipped road layer with the previously prepared 2005 land use raster layer and ensure it matches your project's coordinate system. Use the "Project" tool if necessary to align the coordinate systems.

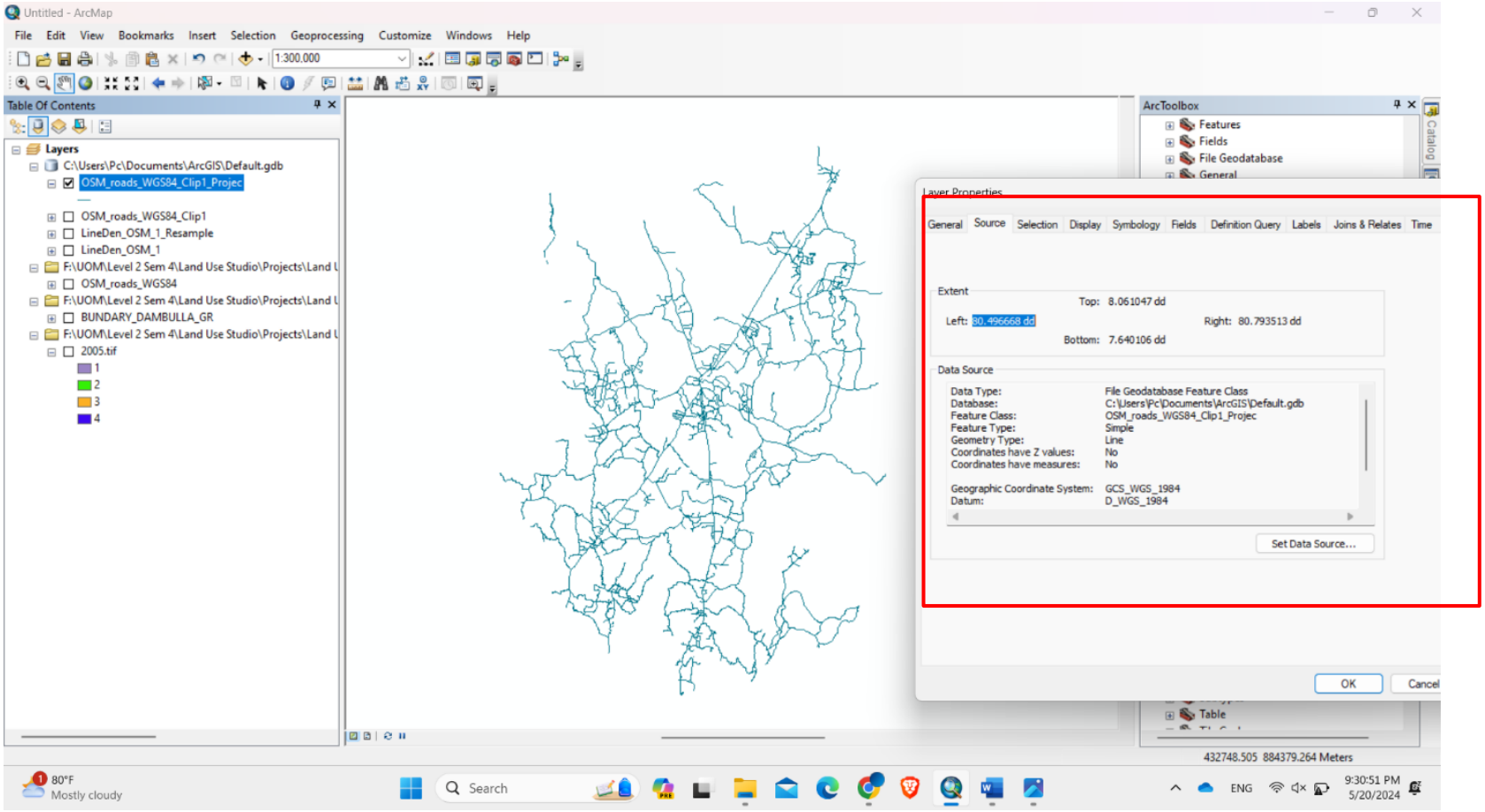

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Table Of Contents
Layers
C:\Users\Pc\Documents\ArcGIS\Default.gdb
OSM_roads_WGS84_Clip1_Projec
OSM_roads_WGS84_Clip1
LineDen_OSM_1_Resample
LineDen_OSM_1
F:\UOM\Level 2 Sem 4\Land Use Studio\Projects\Land U
OSM_roads_WGS84
F:\UOM\Level 2 Sem 4\Land Use Studio\Projects\Land U
BUNDARY_DAMBULLA_GR
F:\UOM\Level 2 Sem 4\Land Use Studio\Projects\Land U
2005.tif
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ArcToolbox
Features
Fields
File Geodatabase
General
Layer Properties
General Source Selection Display Symbology Fields Definition Query Labels Joins & Relates Time
Extent
Top: 8.061047 dd
Left: 80.496668 dd
Right: 80.793513 dd
Bottom: 7.640106 dd
Data Source
Data Type: File Geodatabase Feature Class
Database: C:\Users\Pc\Documents\ArcGIS\Default.gdb
Feature Class: OSM_roads_WGS84_Clip1_Projec
Feature Type: Simple
Geometry Type: Line
Coordinates have Z values: No
Coordinates have measures: No
Geographic Coordinate System: GCS_WGS_1984
Datum: D_WGS_1984
Set Data Source...
OK
Cancel
Table
432748.505 884379.264 Meters
80°F
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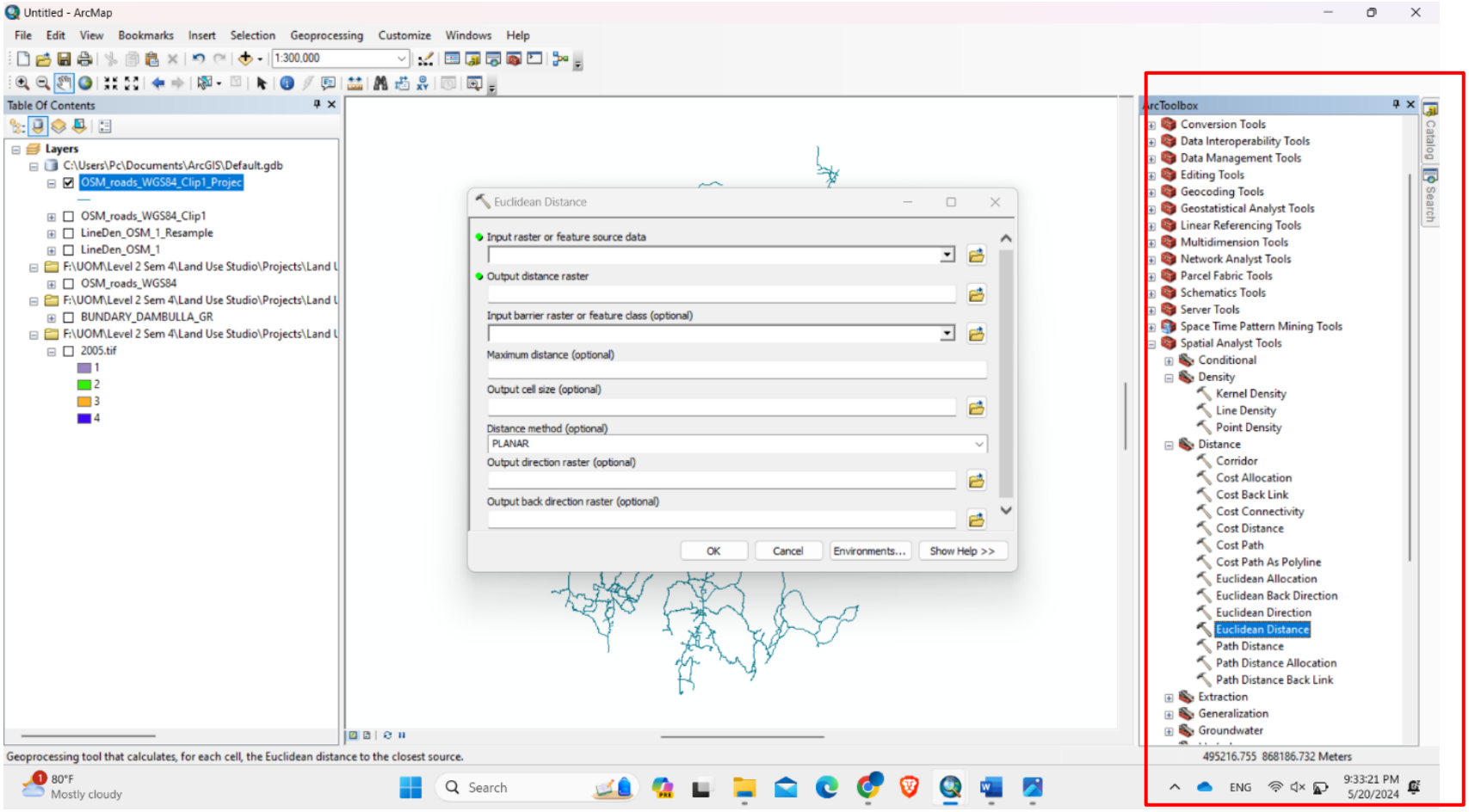
5/20/2024

2. Run the Euclidean Distance Tool

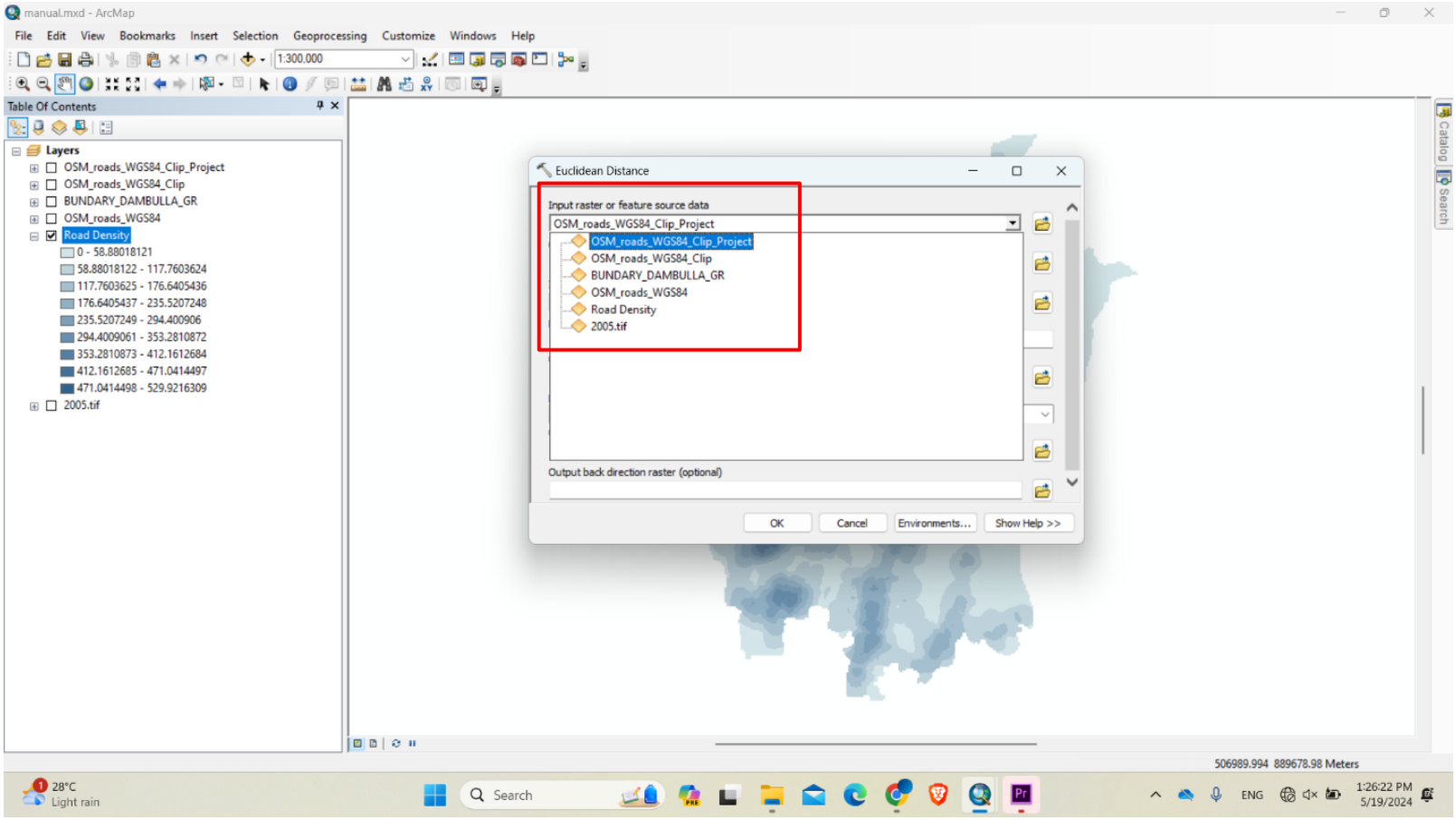
Go to "**ArcToolbox**" and navigate to **Spatial Analyst Tools > Distance > Euclidean Distance**.

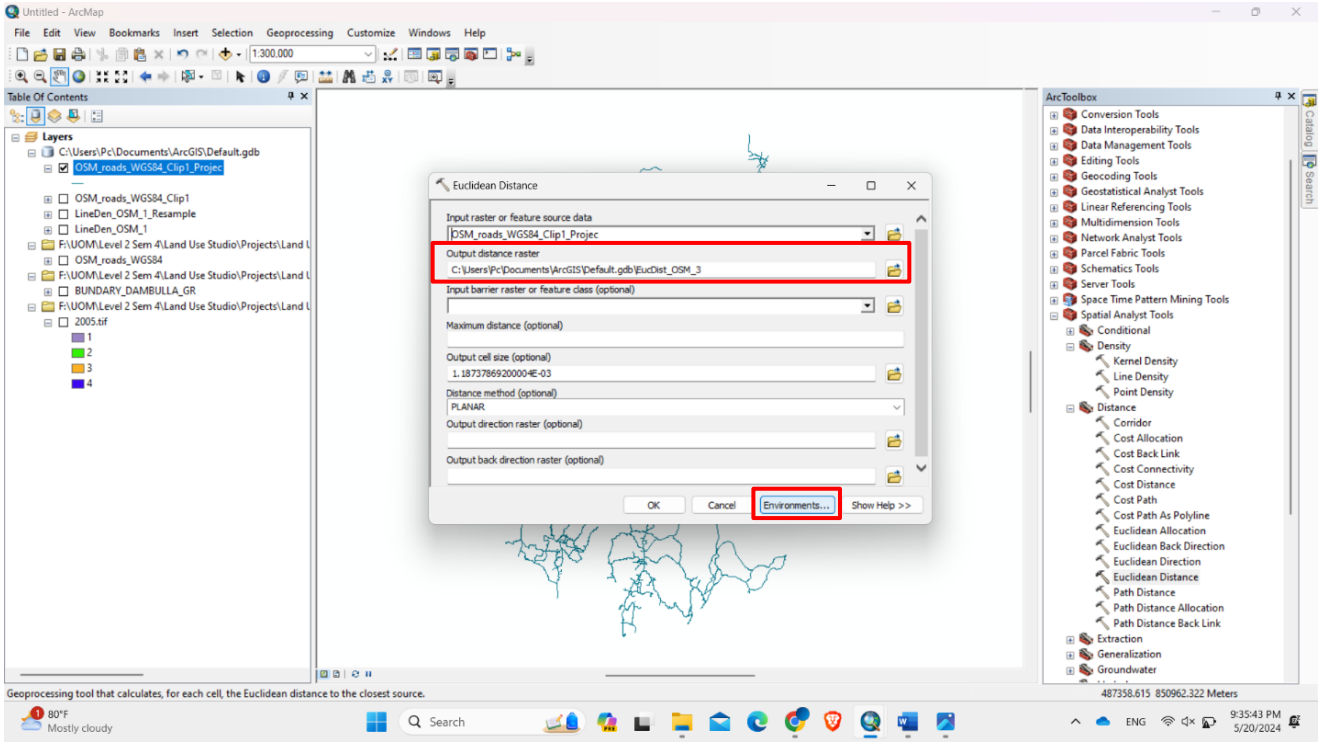


In the Euclidean Distance dialog box, set the following parameters:

I. **Input Raster or Feature Source Data:** Select your clipped road layer.

II. **Output Distance Raster:** Specify the location and name for the output distance raster file.





In the **Environment Settings** dialog box, make the following adjustments.

I. **Processing Extent:**

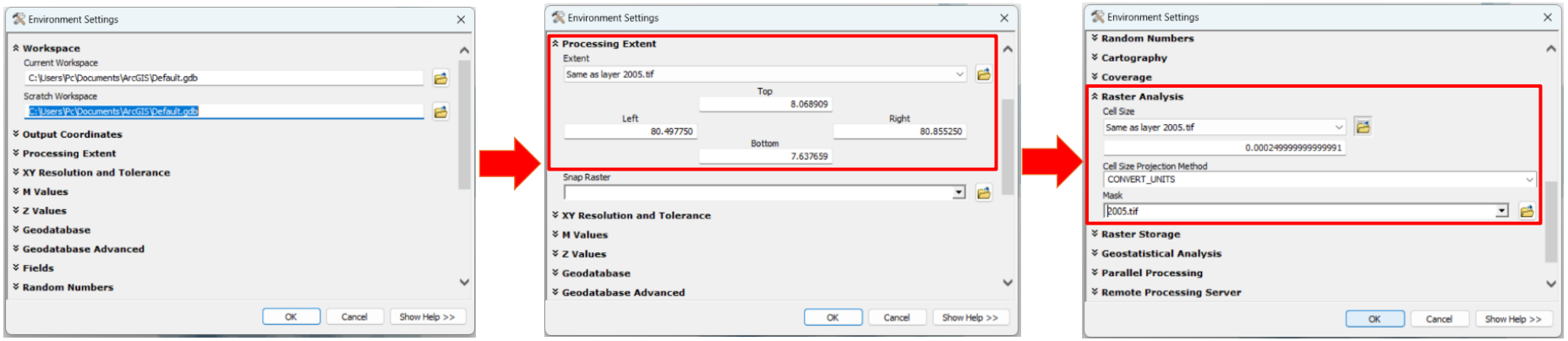
Set the "**Extent**" to match your 2005 land use raster. You can choose the raster layer from the dropdown list to ensure the extent matches exactly.

II. **Raster Analysis:**

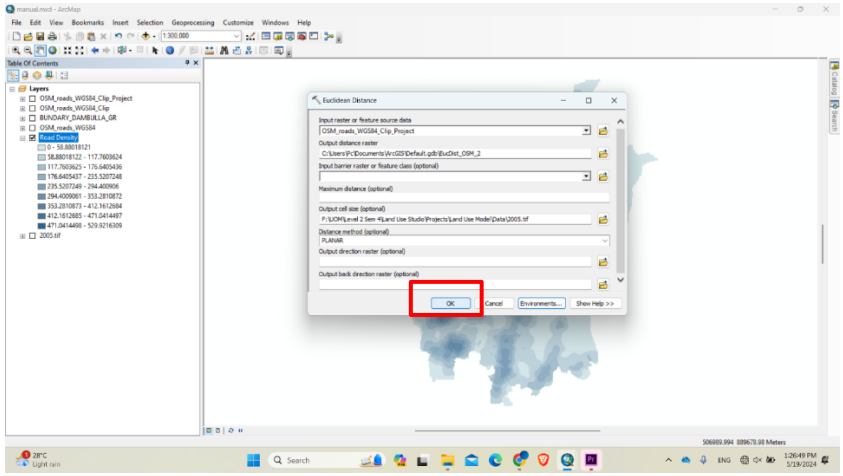
Cell Size: Set the cell size to match the cell size of your 2005 land use raster. You can select the raster layer to automatically match the cell size.

III. **Mask:**

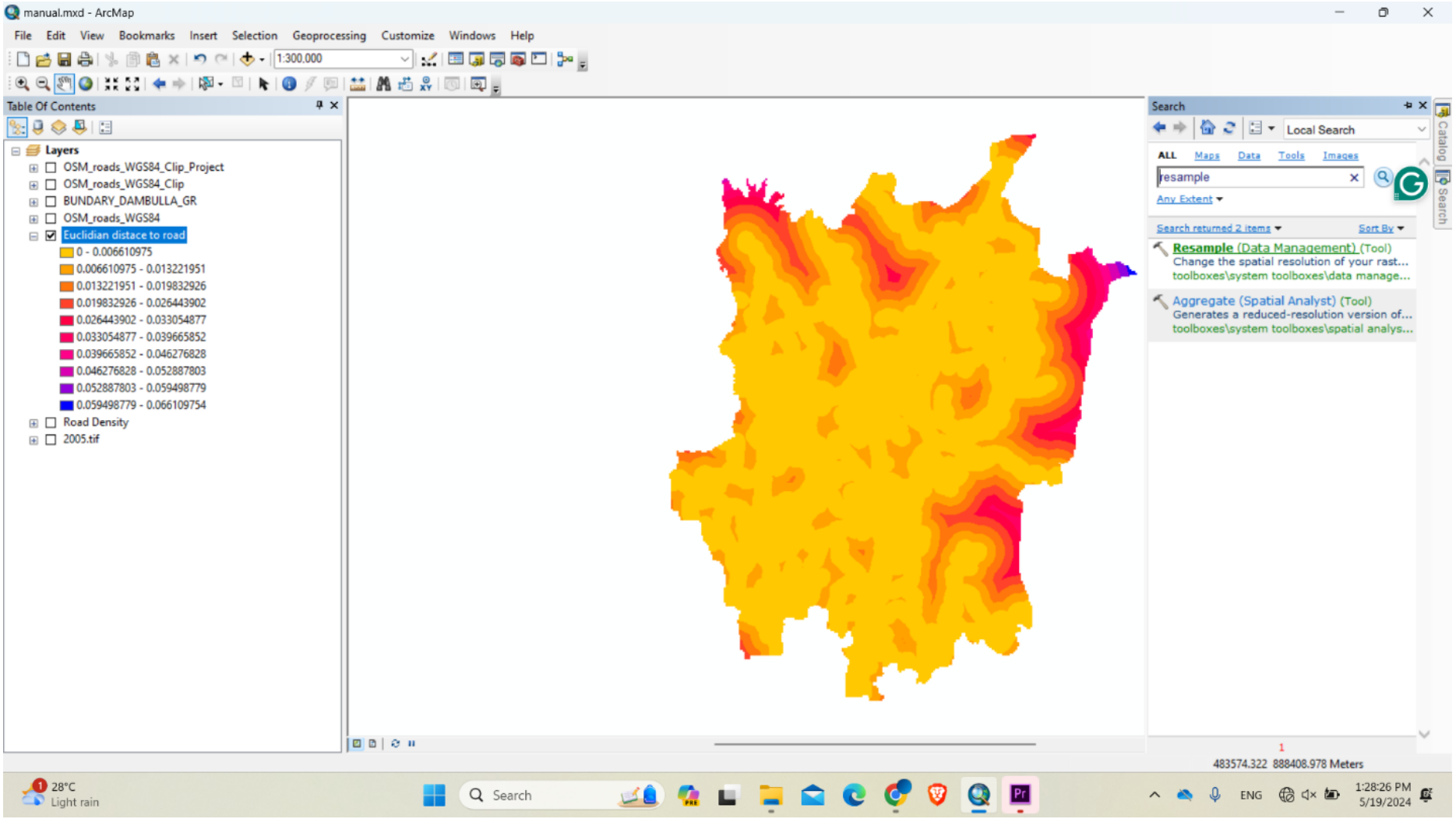
Optionally, you can set a mask to limit the processing to the area covered by your 2005 land use raster.



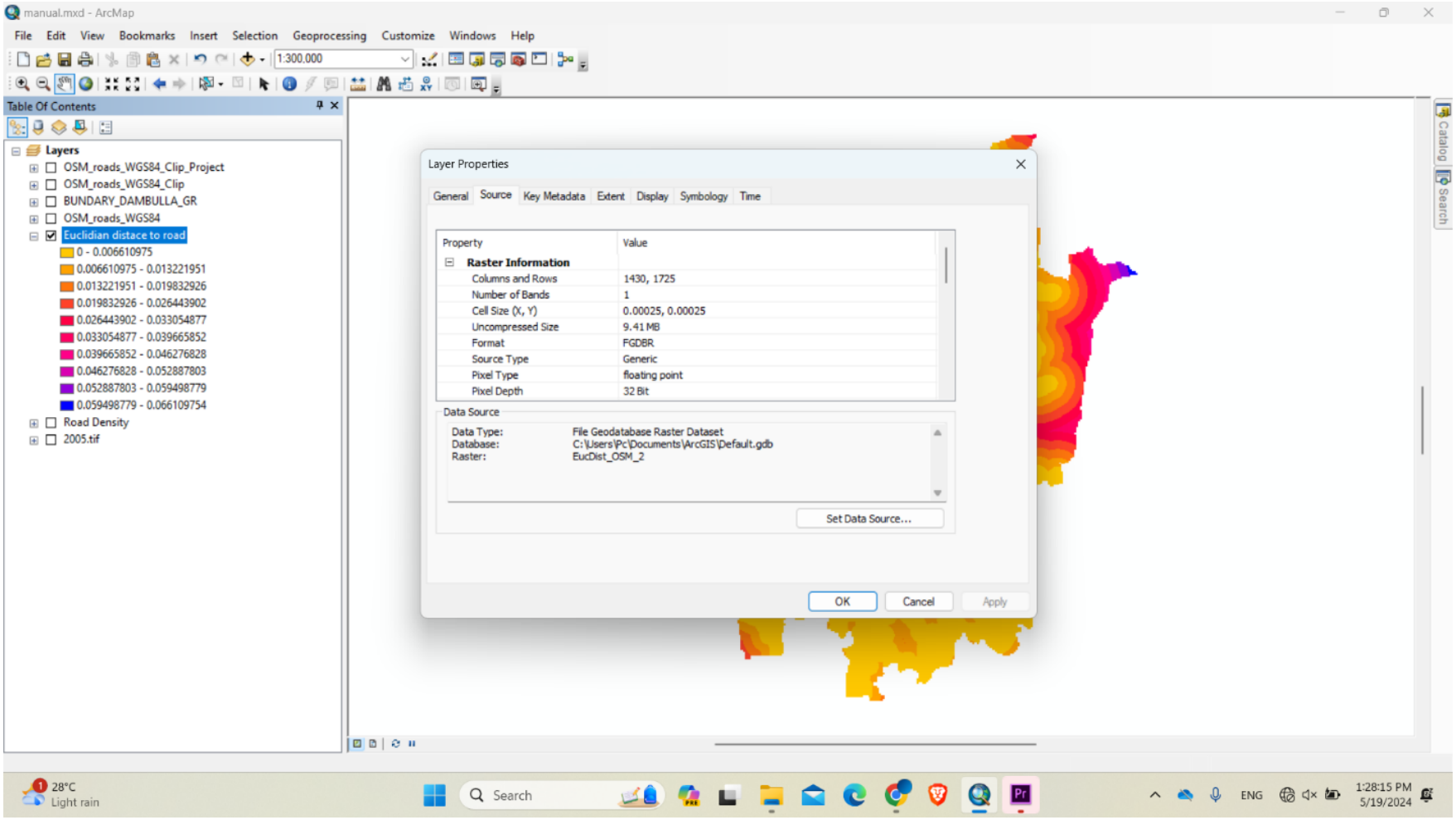
Click "**OK**" to run the tool. The tool will process the data and create a new Euclidean distance raster layer.



Once the Euclidean Distance tool has finished running, the new distance raster layer will be added to your workspace.



- After that, Right-click the new Euclidean distance raster layer in the Table of Contents.
- Select "**Properties**" and go to the "**Source**" tab to confirm that the coordinate system, extent, cell size, and rows/columns match your 2005 land use raster.



If these rows and columns are not equal, resample again and again like the previous road density and create your layer.

4. Euclidean distances to the nearest town centers

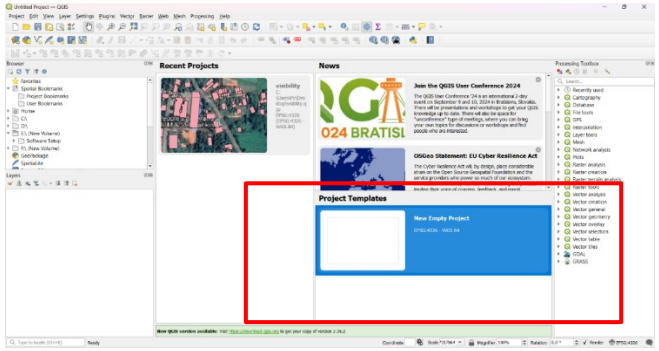
Incorporating the "Euclidean distances to the nearest town centers" as a factor for land use prediction holds several merits. Firstly, proximity to town centers often correlates with patterns of human activity and development. Towns typically serve as hubs of commerce, services, and residential areas, exerting a significant influence on surrounding land use.

The Euclidean distance metric provides a straightforward and intuitive measure of spatial relationship. It offers a clear representation of how far a given location is from the nearest town center, facilitating easy interpretation and integration into predictive models. Considering the distance to town centers acknowledges the influence of infrastructure and amenities associated with urban areas.

Incorporating the Euclidean distances to the nearest town centers as a factor in MOLUSCE enhances its ability to predict land use changes by capturing the spatial dynamics of urbanization, accessibility to amenities, and the influence of infrastructure. By leveraging this metric, MOLUSCE can provide valuable insights into the evolving patterns of land use in diverse landscapes.

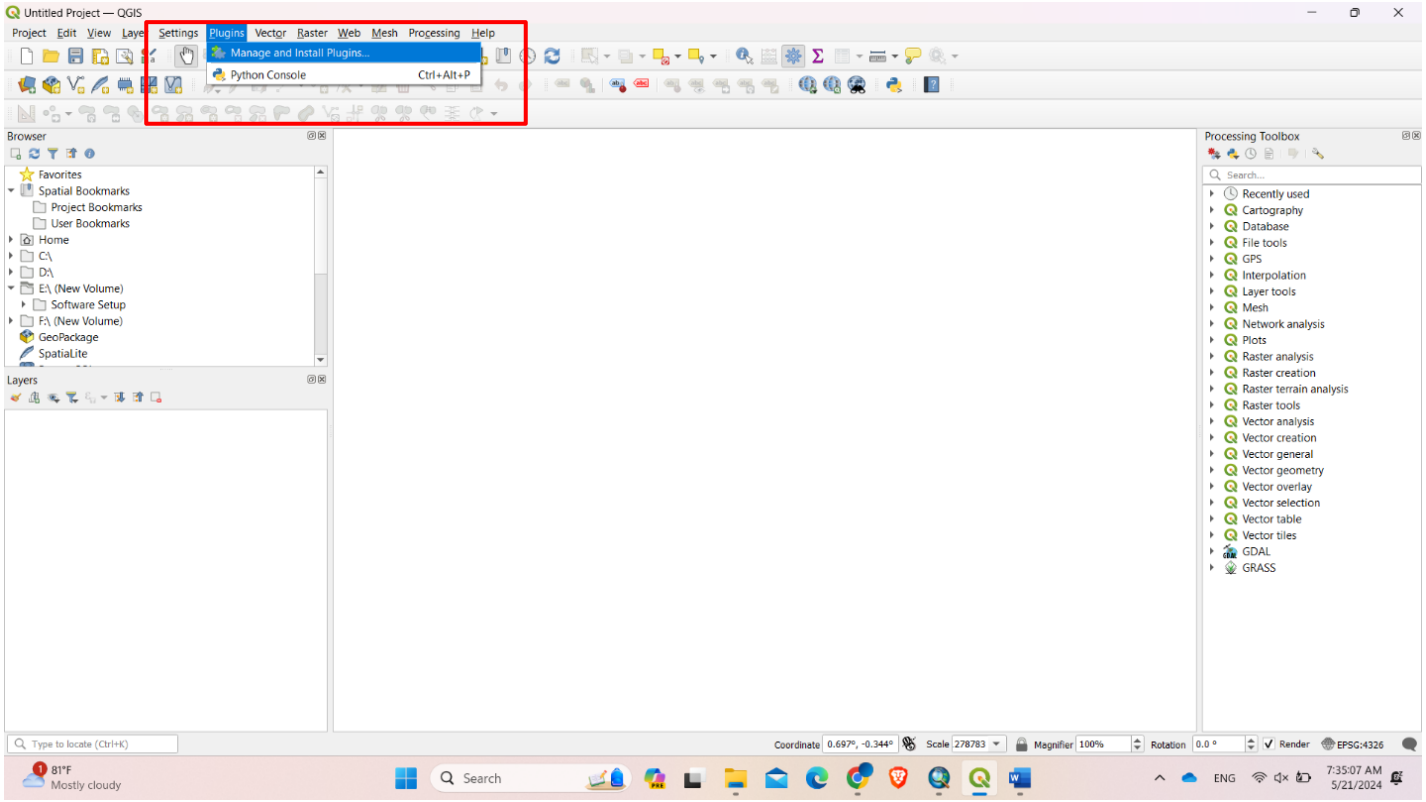
1. **Open QGIS.**

   Open QGIS and create a new project.

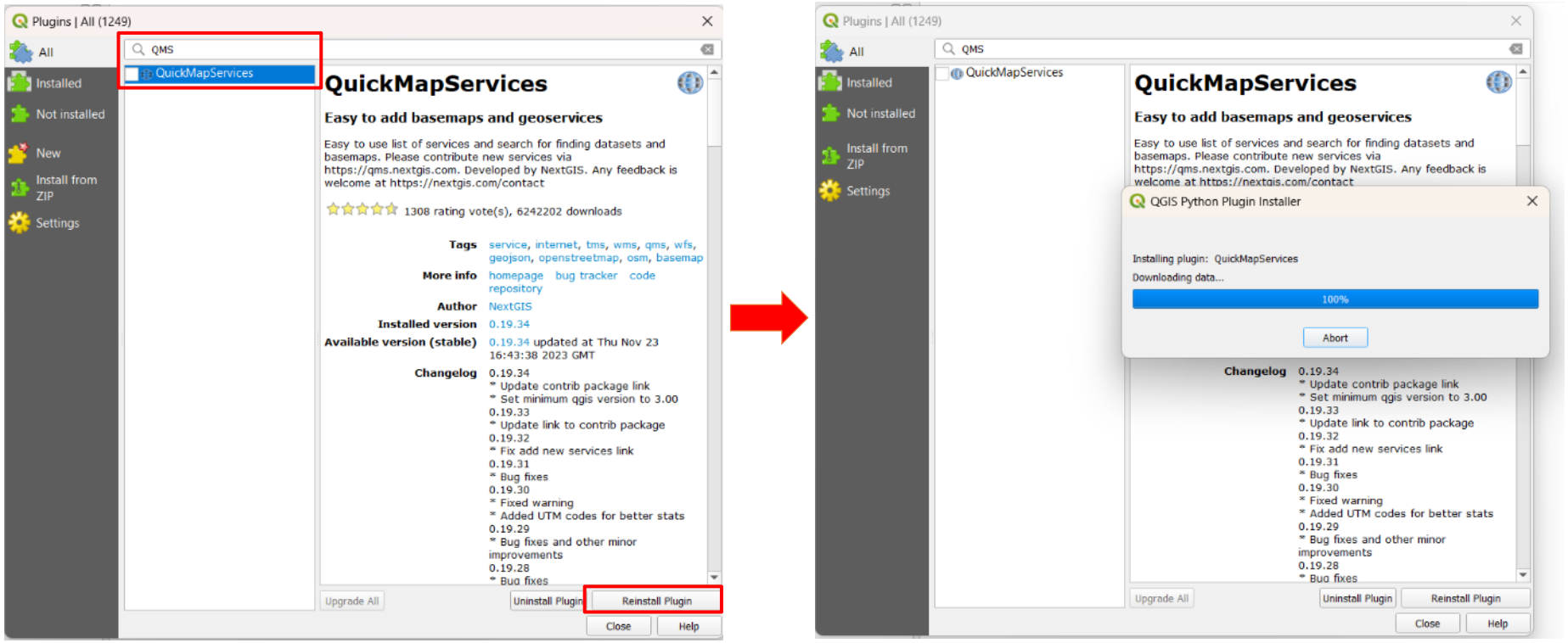


2. Adding a basemap.

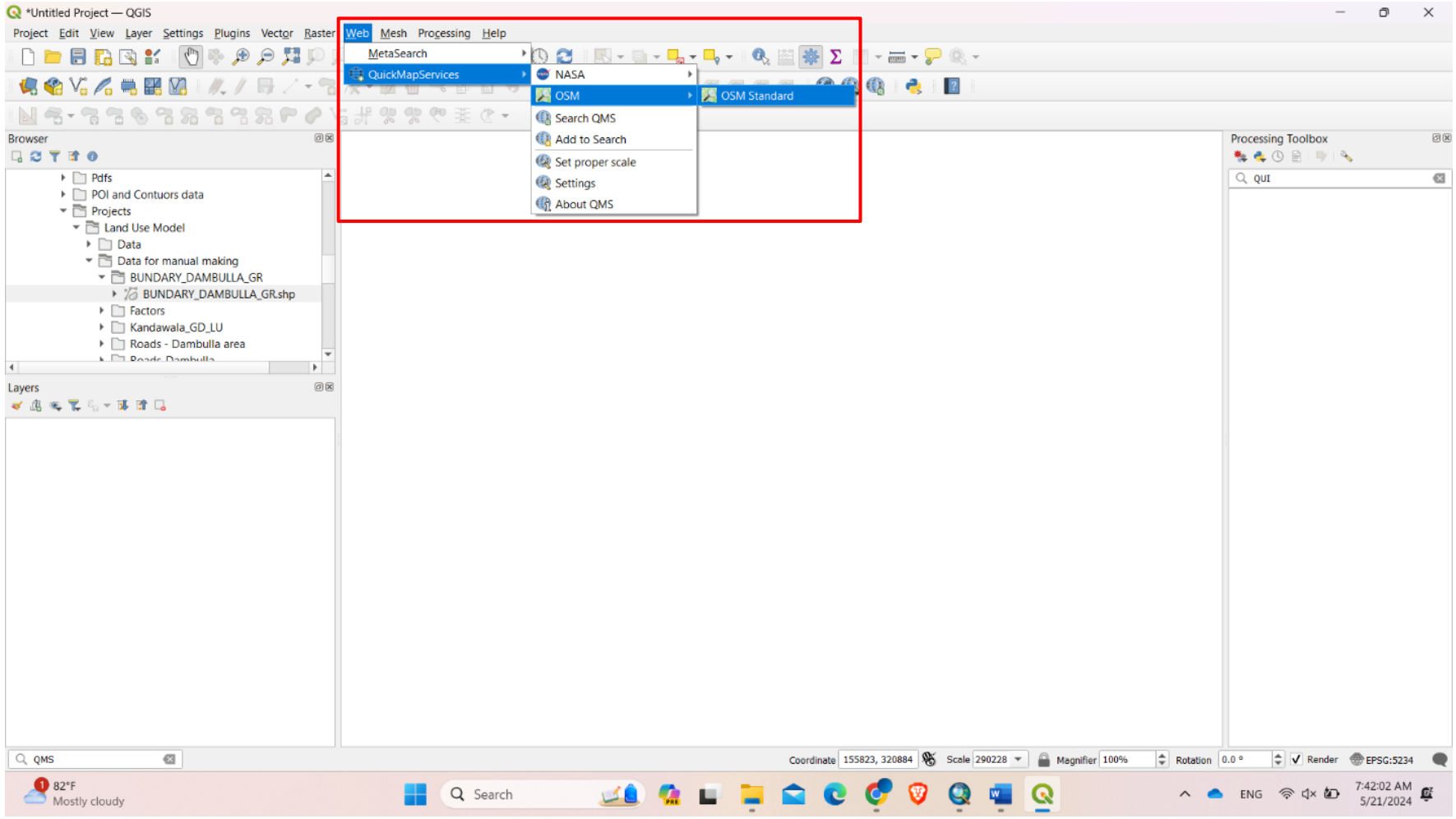
Go to the menu and select **Plugins > Manage and Install Plugins**.



- In the Plugin Manager, search for "**QuickMapServices**" and install it.
- If it is already installed, it will show as "**Reinstall**". If not installed, it will show "**Install**".



- Once installed, go to **Web > QuickMapServices > Settings**.
- In the "**QuickMapServices Settings**" dialog, click on "**More Services**" and then "**Get contributed pack**" (That's for the latest update on maps)
- Close the dialog and go to **Web > QuickMapServices** to choose a base map.
- Select a base map provider from the list (e.g. OpenStreetMap, Google Maps) and click on it to add it to your project.

- 
*Untitled Project — QGIS
Project Edit View Layer Settings Plugins Vector Raster Web Mesh Processing Help
MetaSearch
QuickMapServices
NASA
OSM
OSM Standard
Search QMS
Add to Search
Set proper scale
Settings
About QMS
Browser
Pdfs
POI and Contuors data
Projects
Land Use Model
Data
Data for manual making
BUNDARY_DAMBULLA_GR
BUNDARY_DAMBULLA_GR.shp
Factors
Kandawala_GD_LU
Roads - Dambulla area
Layers
Processing Toolbox
QUI
QMS
Coordinate 155823, 320884
Scale 290228
Magnifier 100%
Rotation 0.0 °
Render
EPSG:5234
82°F
Mostly cloudy
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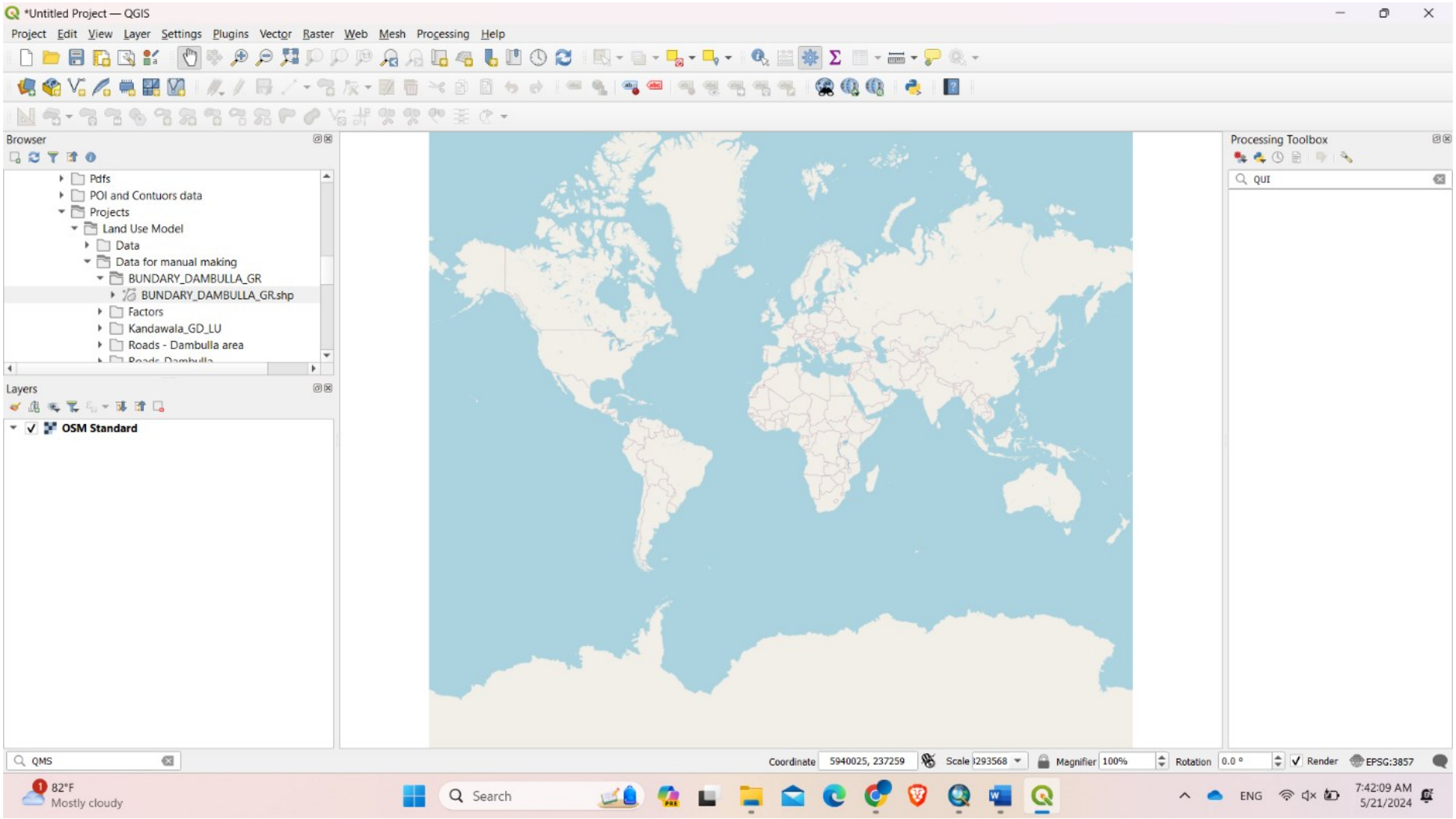
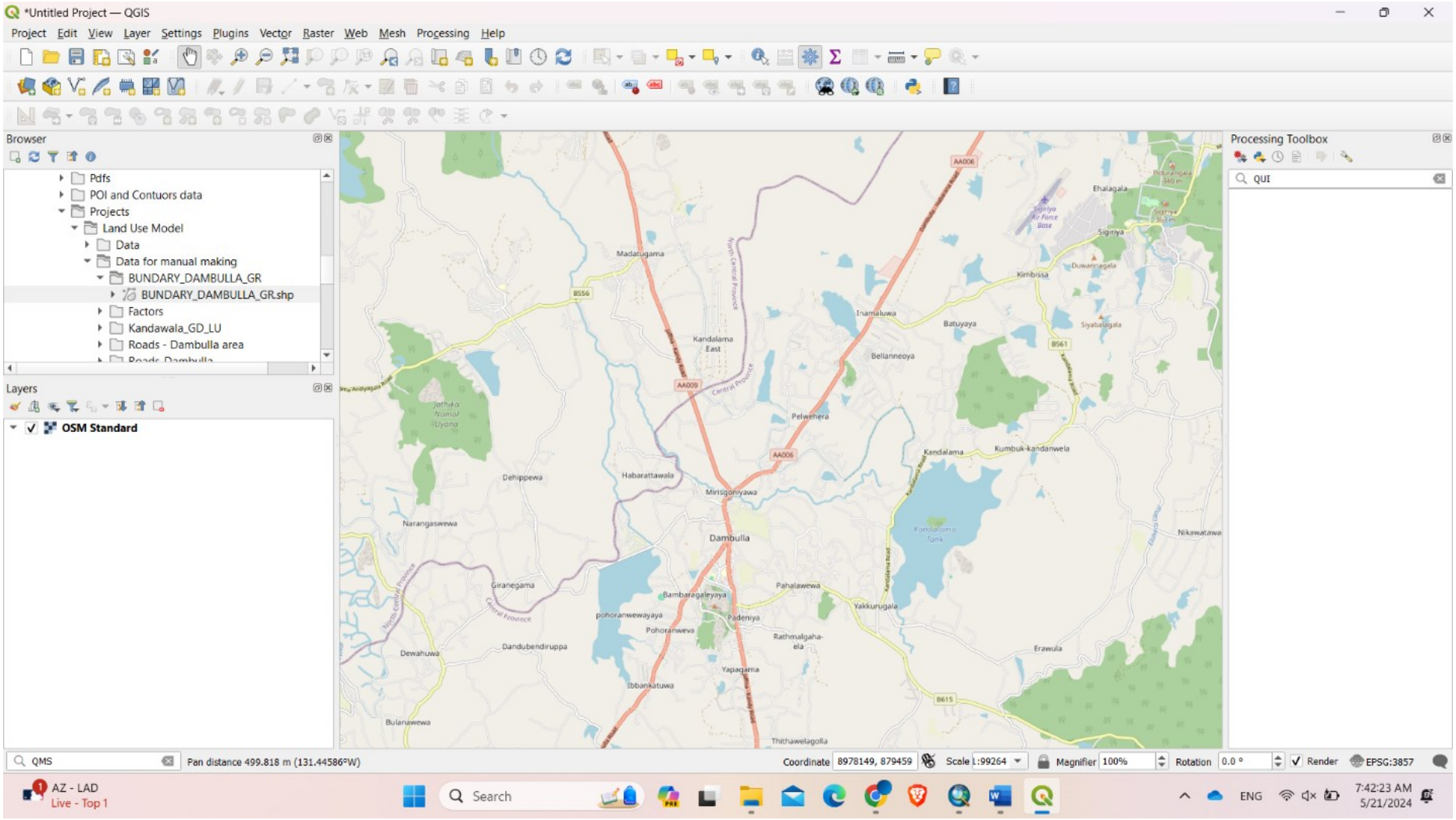
5/21/2024

The base map will be added as a new layer in the Layers Panel.

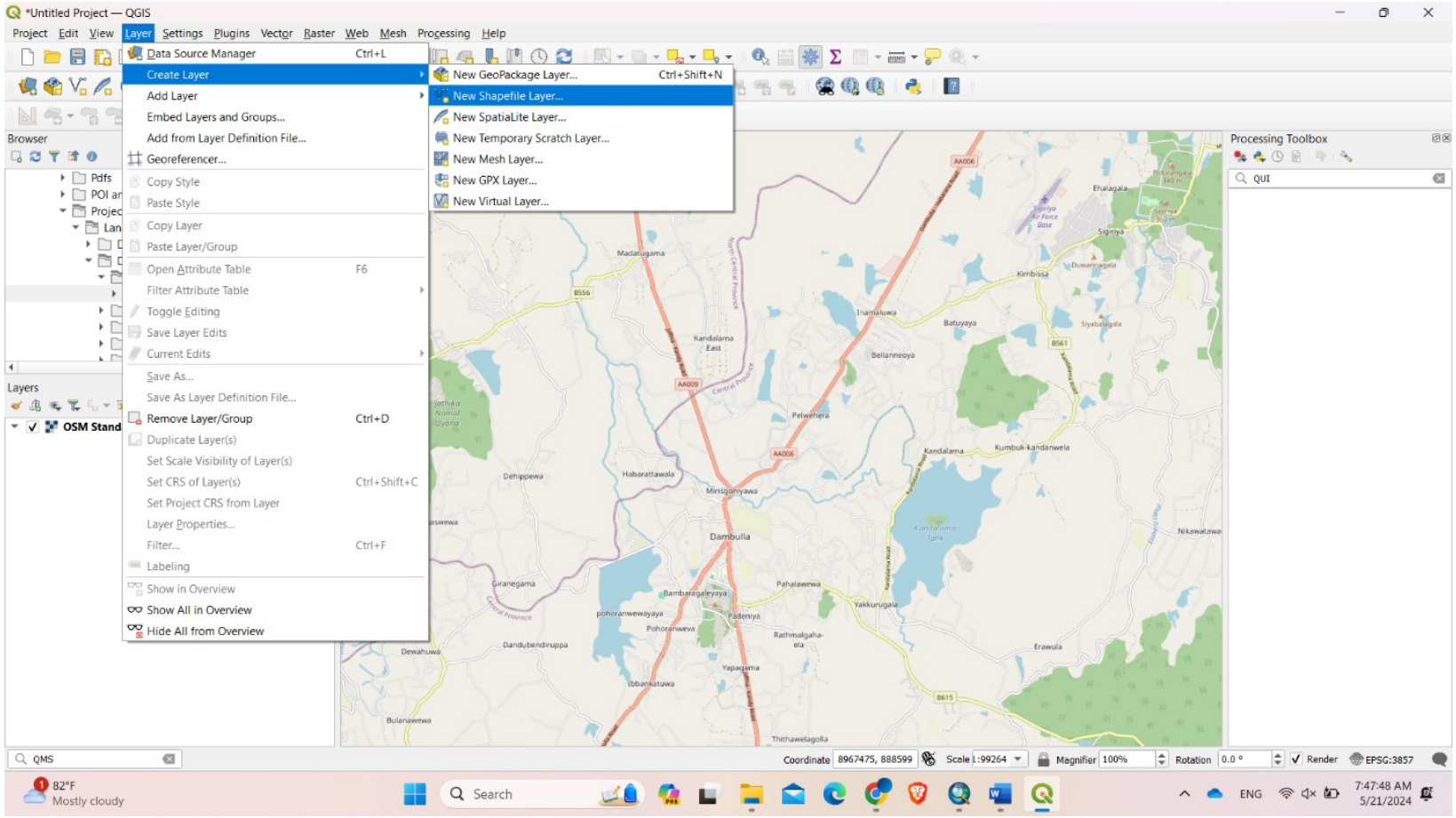


Use the mouse cursor and zoom to your area.

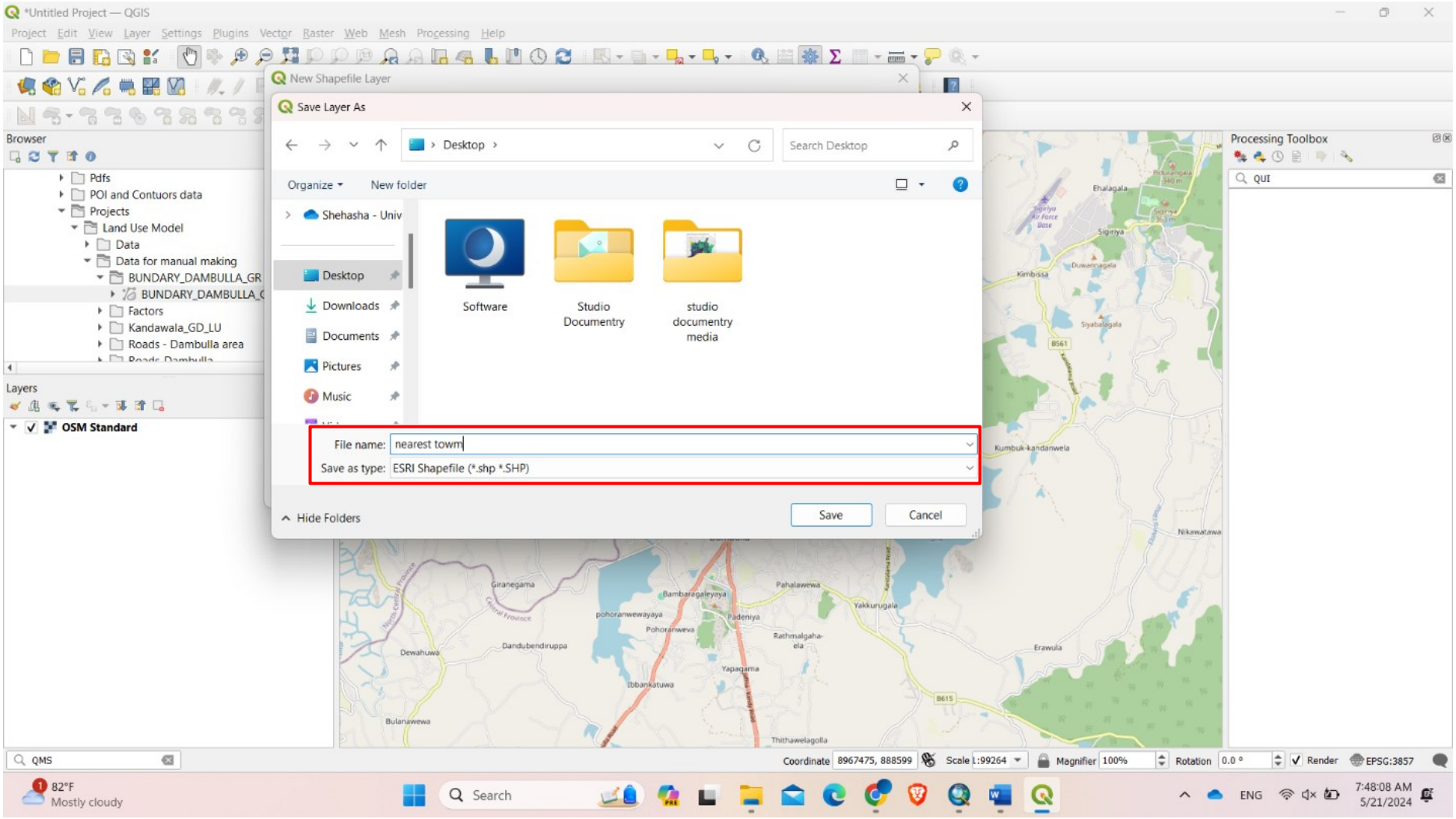


3. Creating a Shapefile.

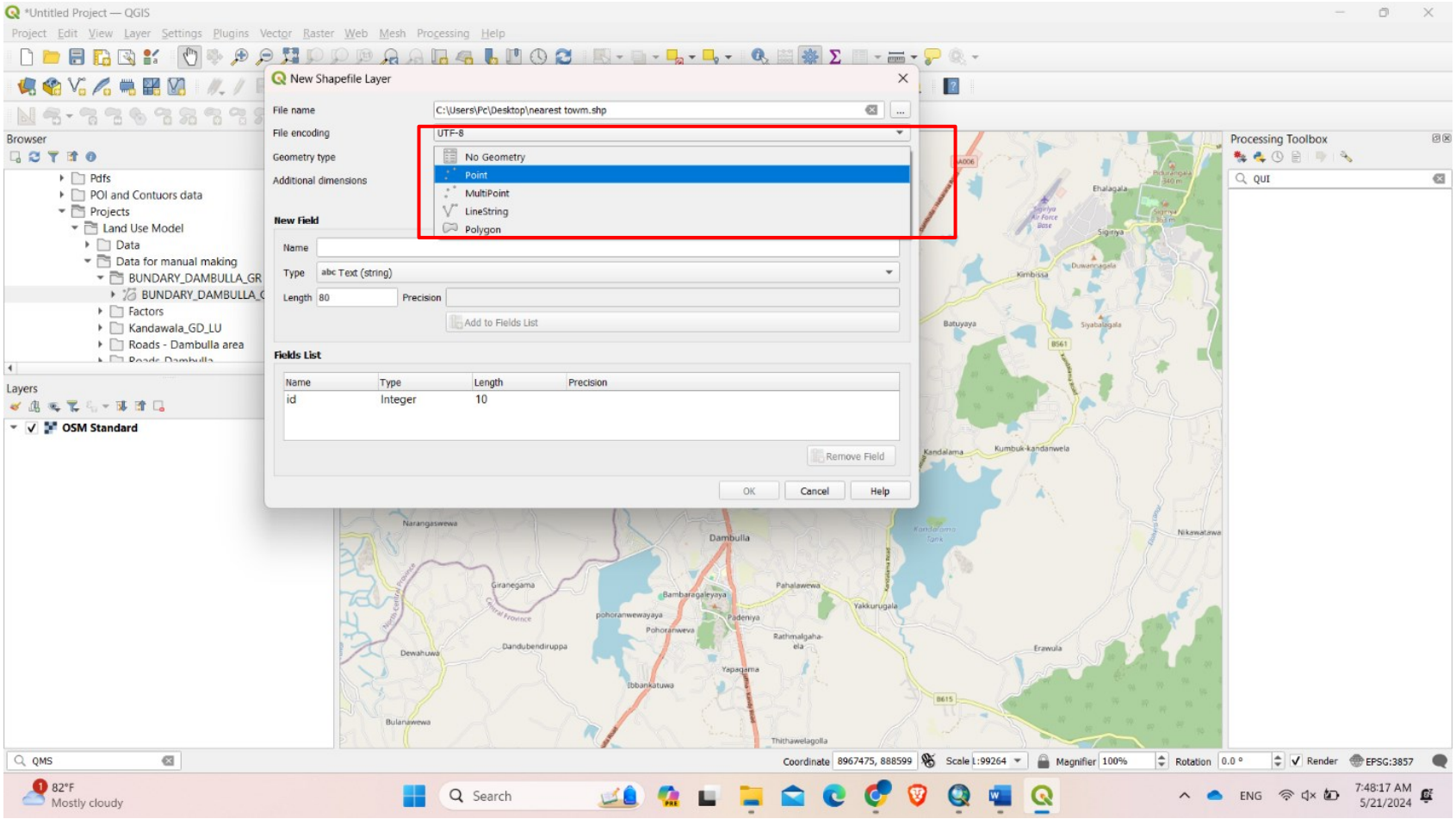
In the menu, go to **Layer > Create Layer > New Shapefile Layer**.



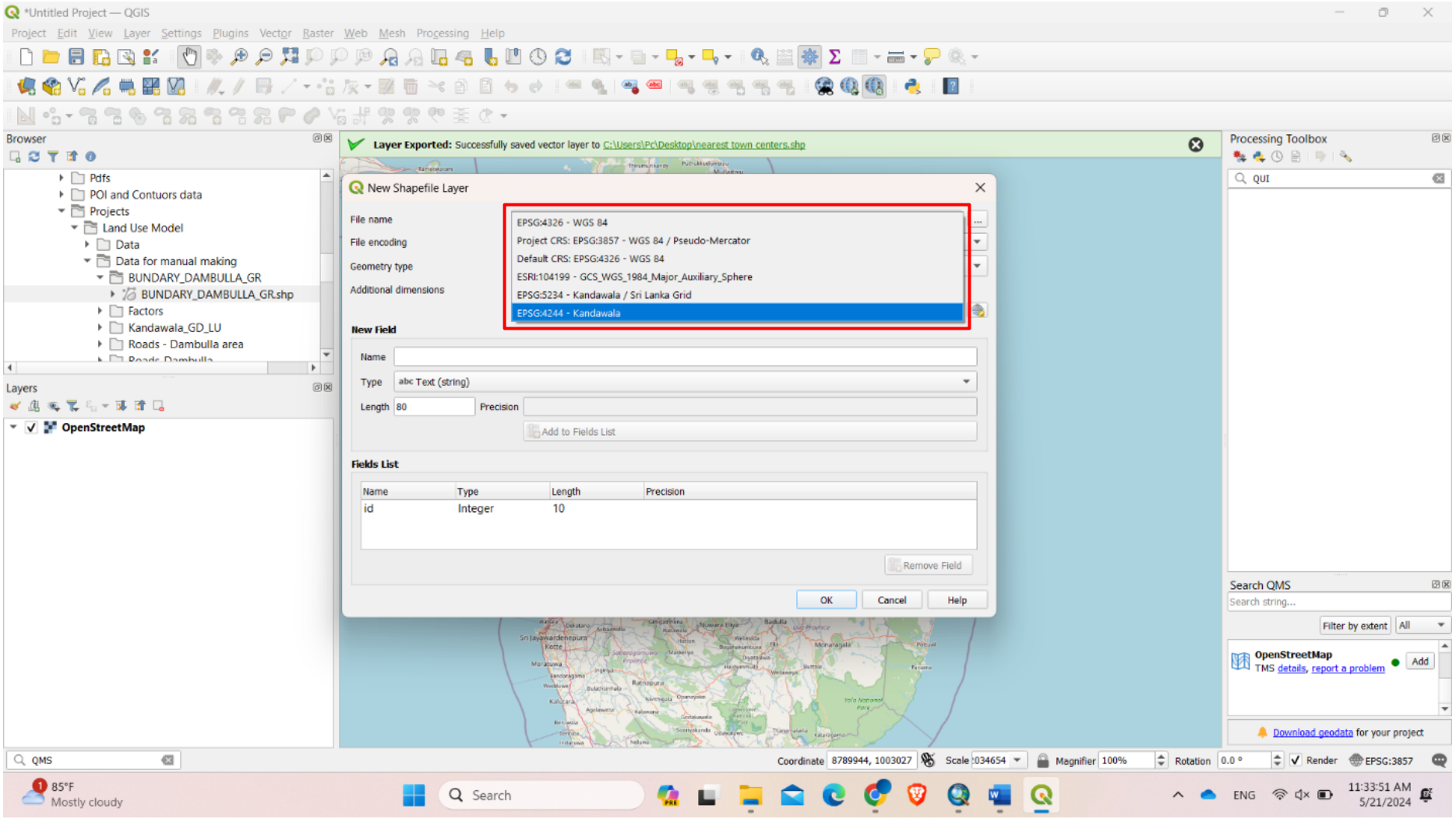
Choose a directory to save the shapefile and give it a name.



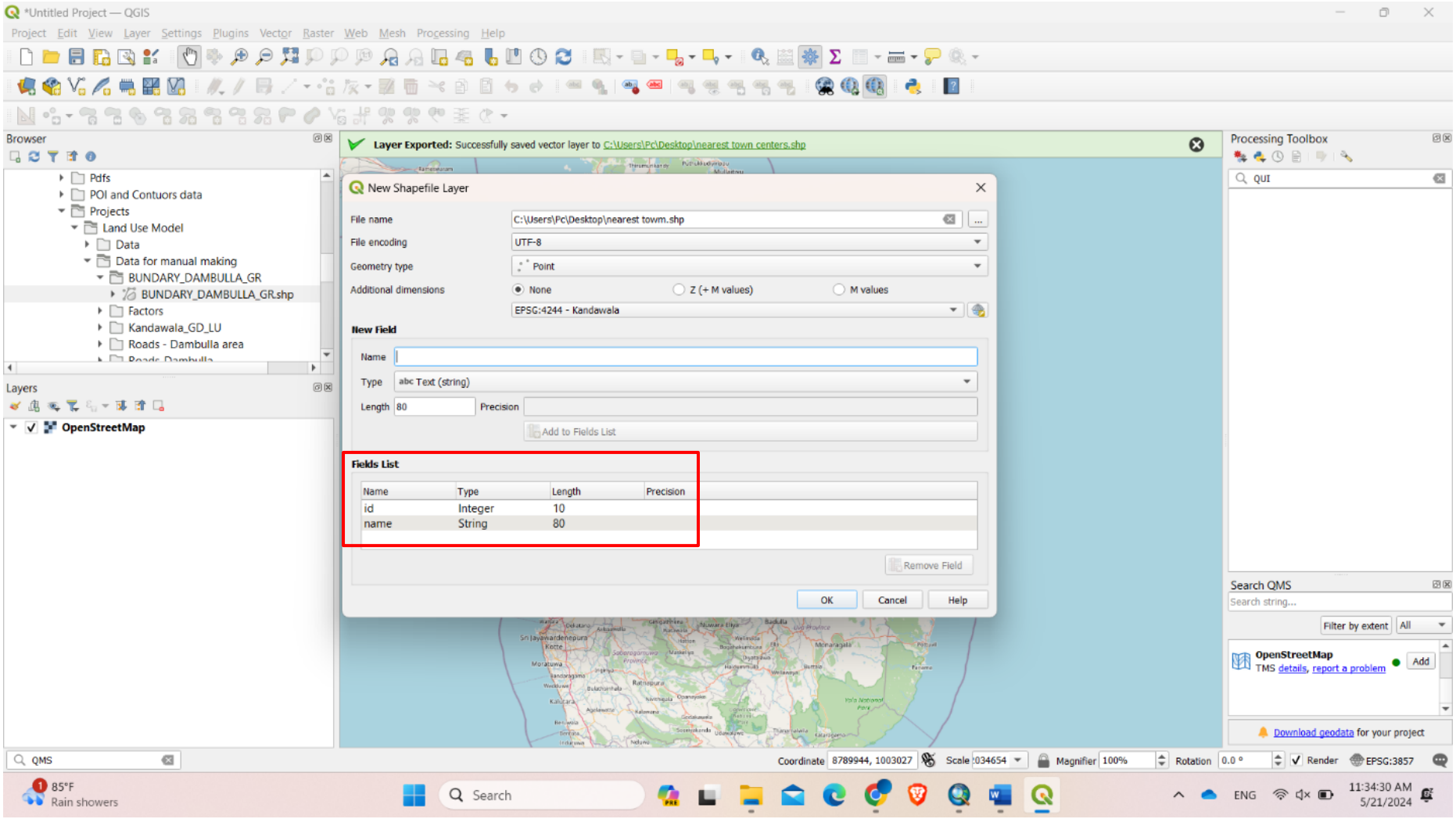
In the "**New Vector Layer**" dialog box, specify the type of feature (point, line, or polygon), coordinate reference system (CRS), and attribute fields. Here I want to mark towns and therefore select points.



Then Select the coordinate system.

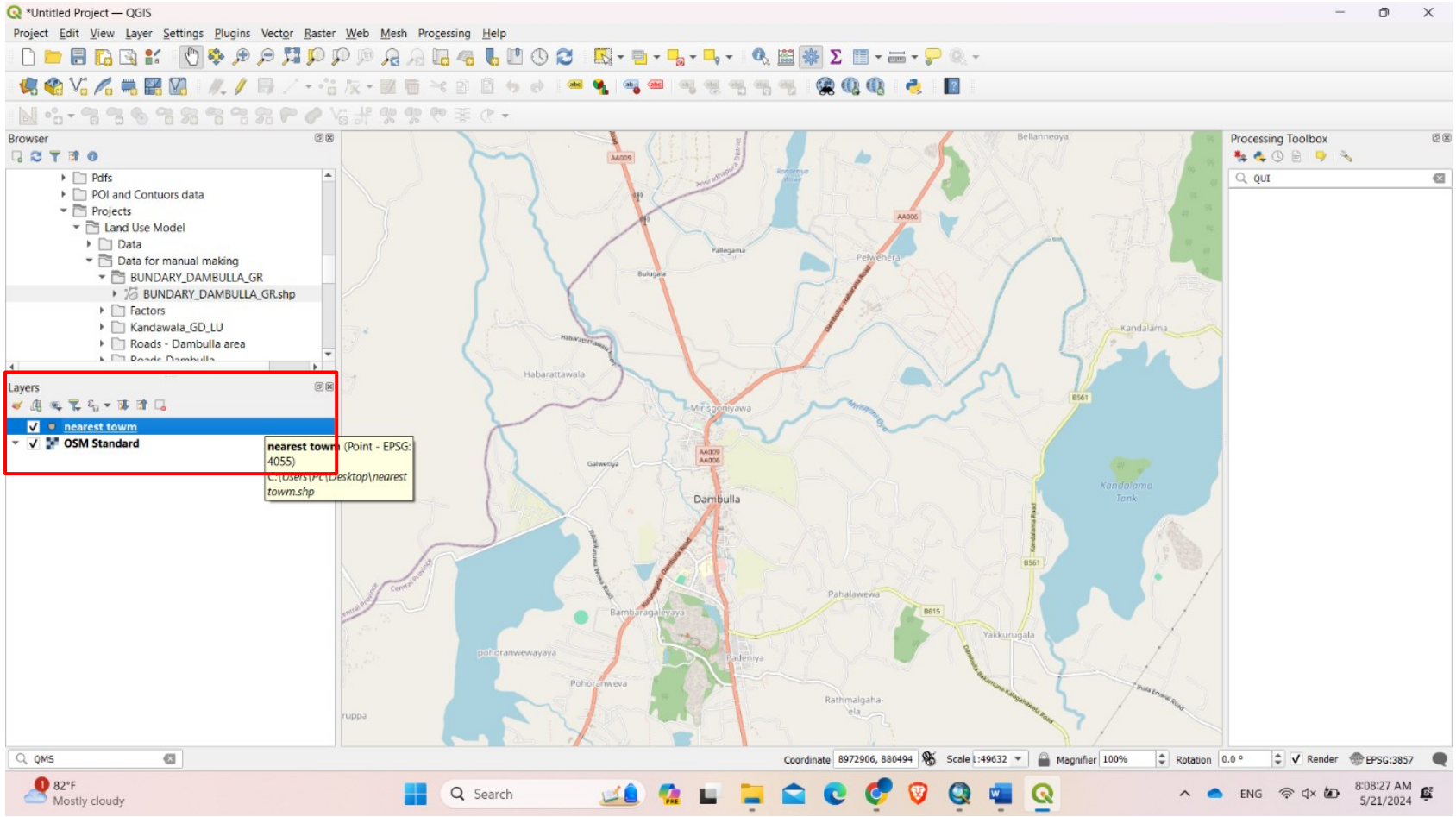


At this point, a column was added as a name to the attribute table.



Click "**OK**" to create the shapefile.

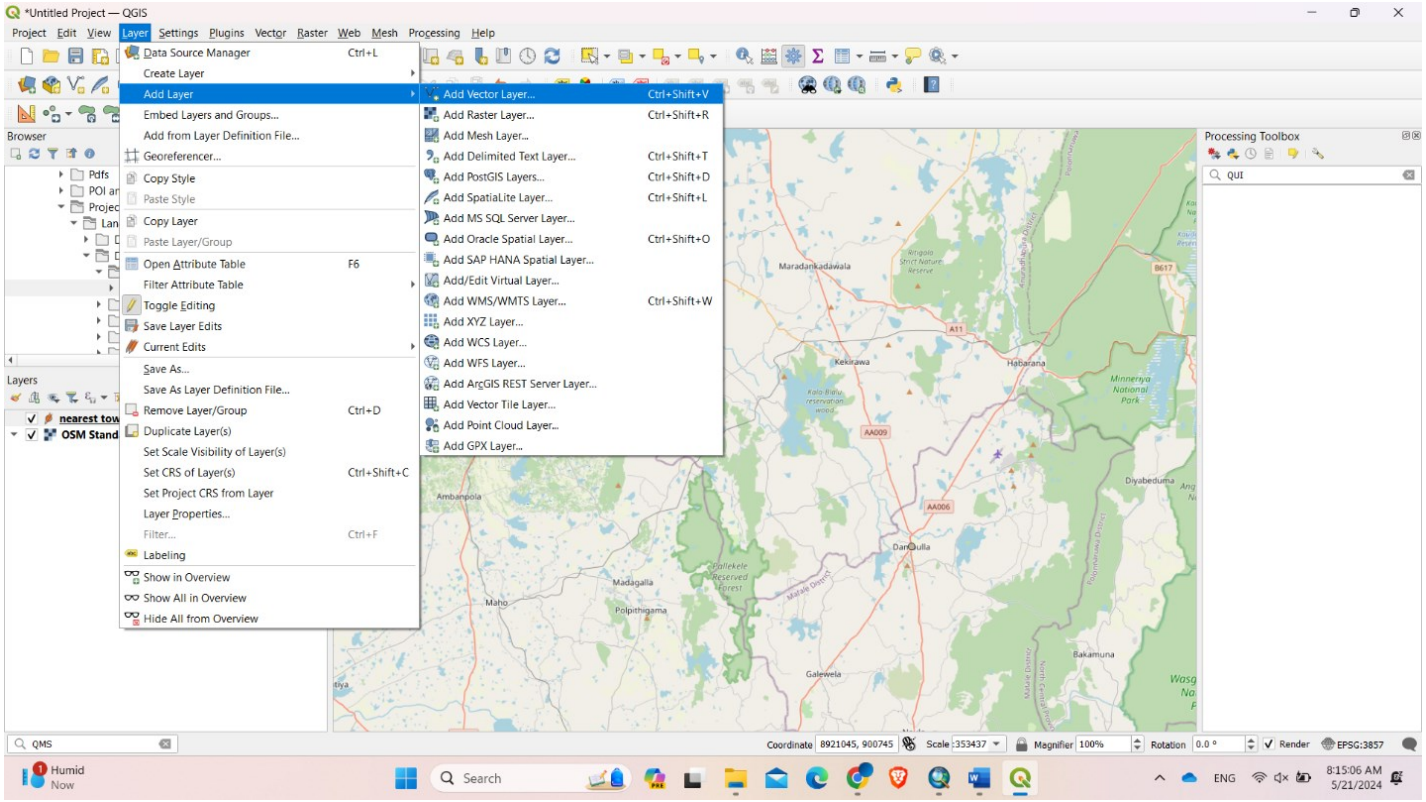
Now the (.shp) file we created appears in the layers panel on the left.



To facilitate the identification of relevant areas, we have included the boundary shapefile for the Greater Dambulla area. This addition allows for easier and more accurate delineation of the specified region.

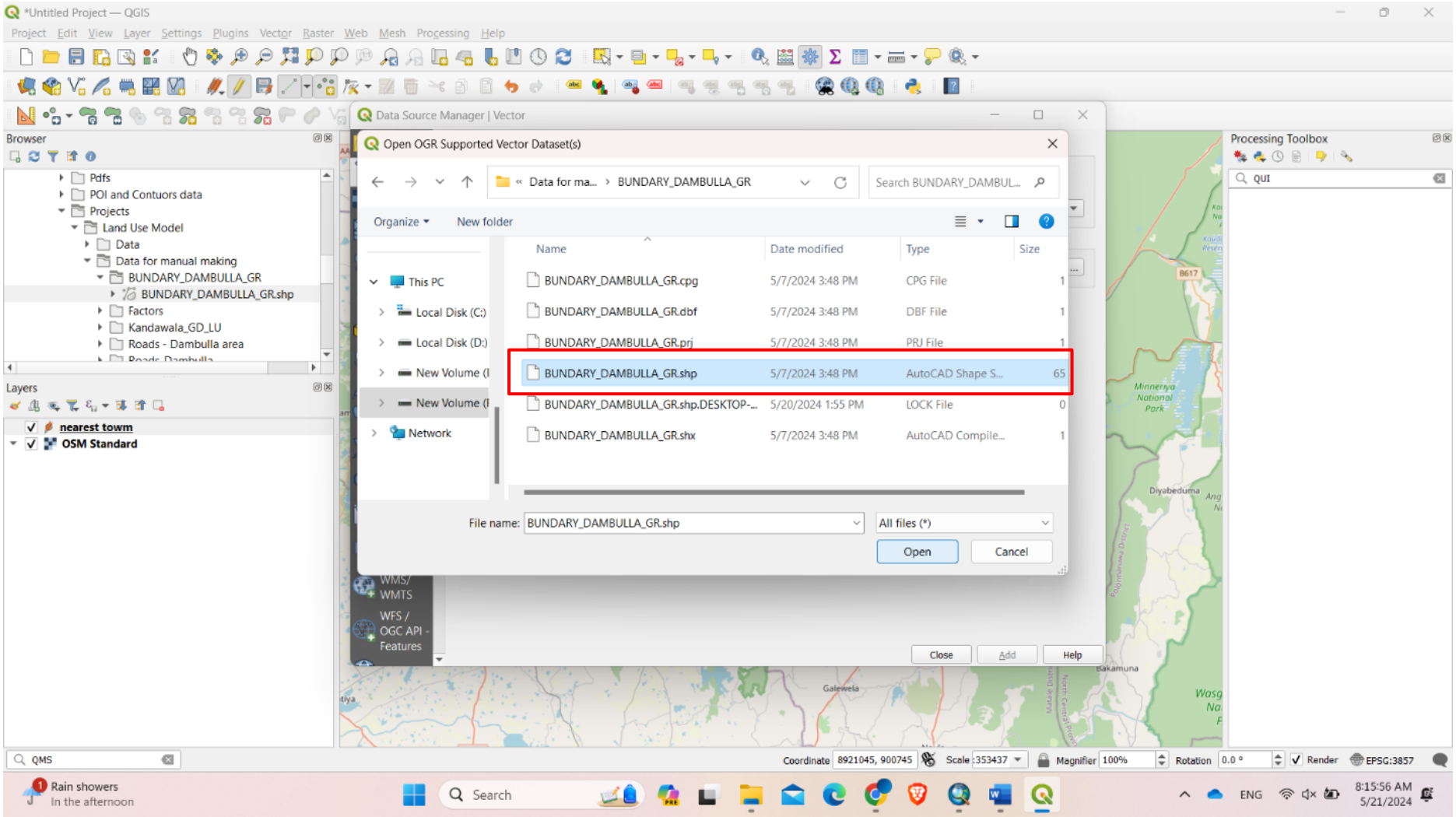
4. Add the boundary Shapefile layer.

- Go to **Layer > Add Layer > Add Vector Layer**.
- Alternatively, you can click the Add Vector Layer button in the Data Source Manager toolbar.
- Open the Data Source Manager
- In the Data Source Manager dialog, click the ... button next to the Vector Dataset(s) field.

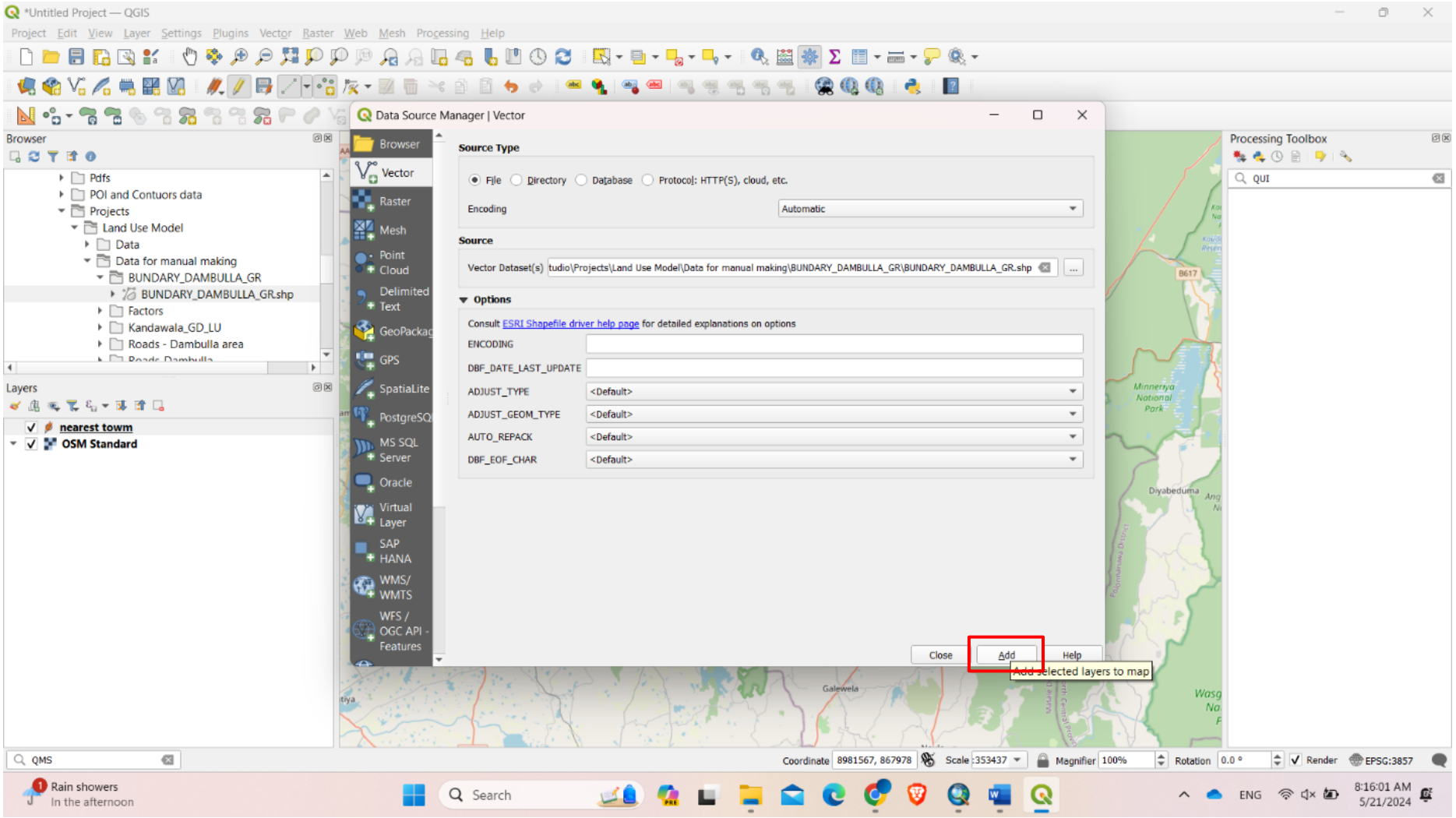


- Navigate to the location where your boundary shapefile is stored.

- **Select the Shapefile**
- Select the shapefile (.shp extension) you want to add.


*Untitled Project — QGIS
Project Edit View Layer Settings Plugins Vector Raster Web Mesh Processing Help
Data Source Manager | Vector
Open OGR Supported Vector Dataset(s)
Data for ma... › BUNDARY_DAMBULLA_GR
Search BUNDARY_DAMBUL...
Organize
New folder
Name
Date modified
Type
Size
BUNDARY_DAMBULLA_GR.cpg 5/7/2024 3:48 PM CPG File 1
BUNDARY_DAMBULLA_GR.dbf 5/7/2024 3:48 PM DBF File 1
BUNDARY_DAMBULLA_GR.prj 5/7/2024 3:48 PM PRJ File 1
BUNDARY_DAMBULLA_GR.shp 5/7/2024 3:48 PM AutoCAD Shape S... 65
BUNDARY_DAMBULLA_GR.shp.DESKTOP-... 5/20/2024 1:55 PM LOCK File 0
BUNDARY_DAMBULLA_GR.shx 5/7/2024 3:48 PM AutoCAD Compile... 1
This PC
Local Disk (C:)
Local Disk (D:)
New Volume (I
New Volume (I
Network
File name: BUNDARY_DAMBULLA_GR.shp
All files (*)
Open
Cancel
Browser
Pdfs
POI and Contuors data
Projects
Land Use Model
Data
Data for manual making
BUNDARY_DAMBULLA_GR
BUNDARY_DAMBULLA_GR.shp
Factors
Kandawala_GD_LU
Roads - Dambulla area
Layers
nearest towm
OSM Standard
WMS/ WMTS
WFS / OGC API - Features
Close
Add
Help
Processing Toolbox
QUI
QMS
Coordinate 8921045, 900745
Scale 1:353437
Magnifier 100%
Rotation 0.0 °
Render
EPSG:3857
Rain showers
In the afternoon
Search
ENG
8:15:56 AM
5/21/2024

Back in the Data Source Manager dialog, click “**Add**”.



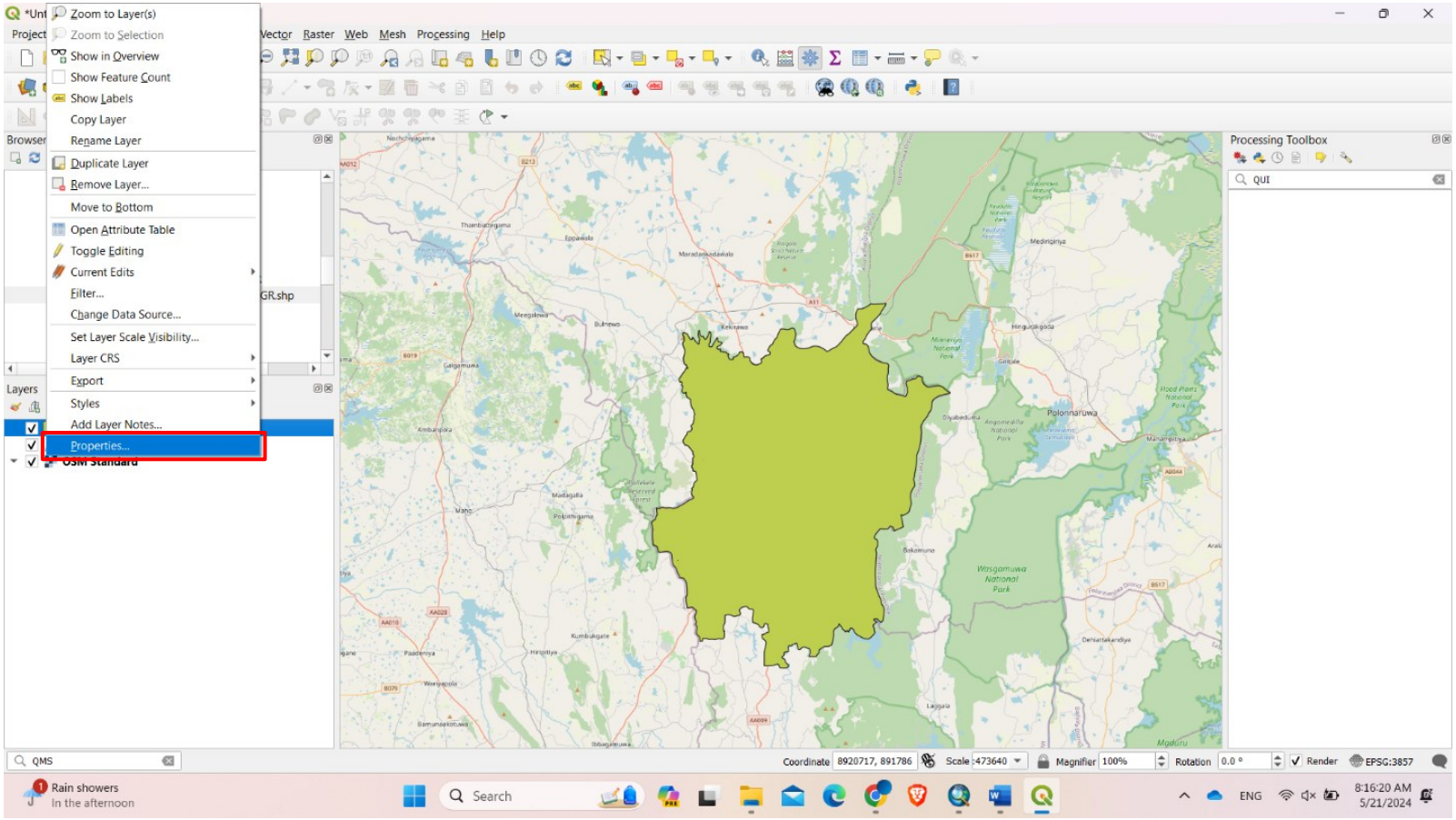
Your boundary shapefile will now be added to the Layers Panel.

Verify the Layer

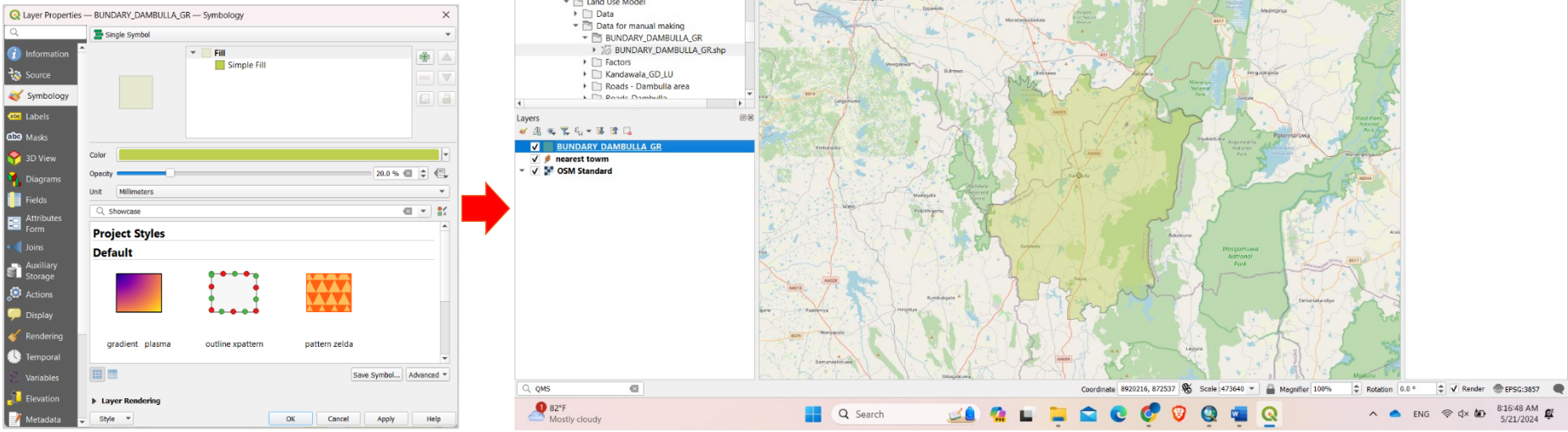
- Ensure the boundary layer appears in the Layers Panel.
- You can right-click on the layer and select Zoom to Layer to view the full extent of your boundary.

Adjust Layer Styling (Optional)

- To change the appearance of the boundary, right-click on the layer and select Properties.

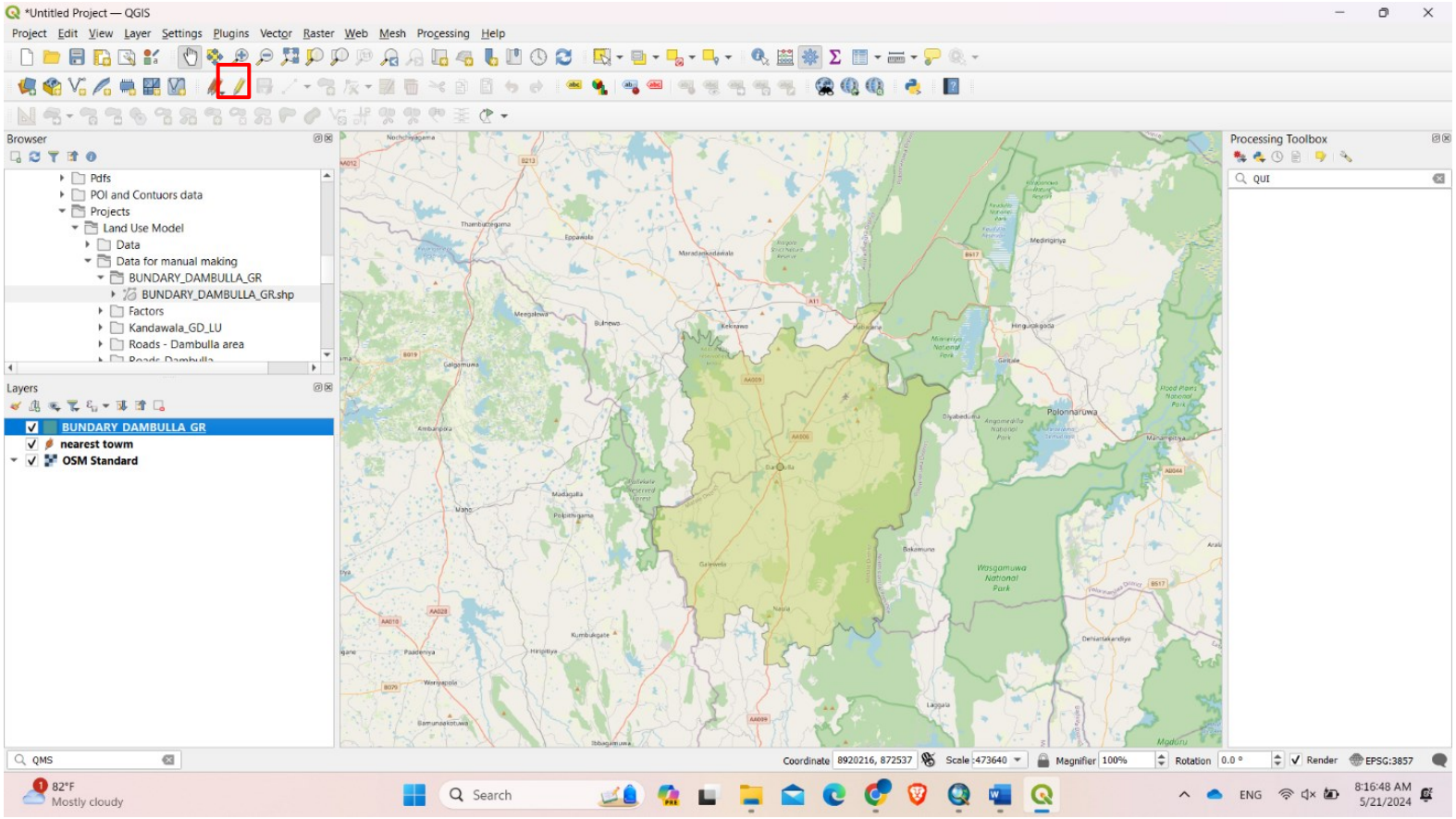


- In the Layer Properties dialog, go to the Symbology tab and adjust the style settings as needed.
- Here I have adjusted the opacity.

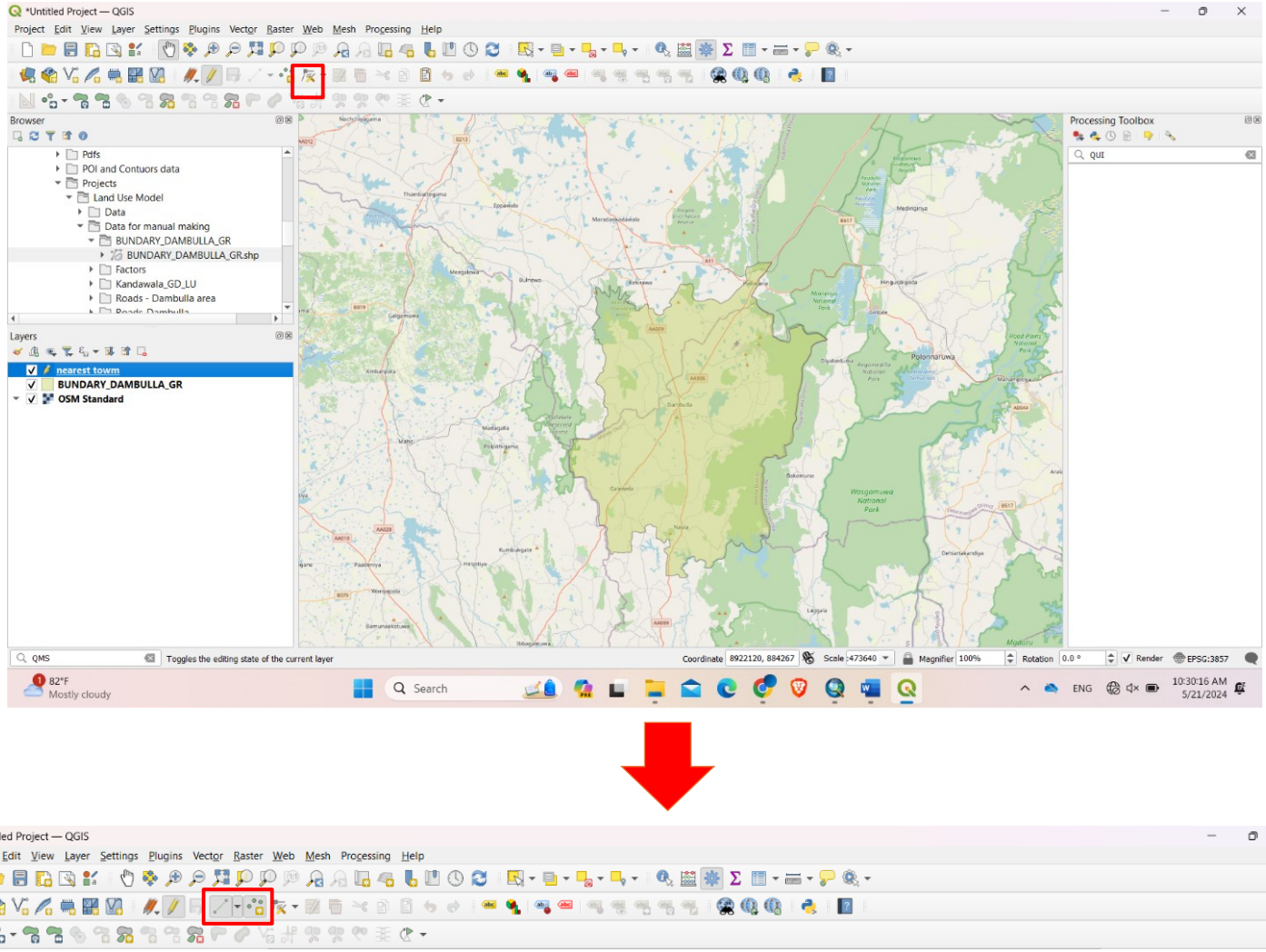


5. Digitizing Features.

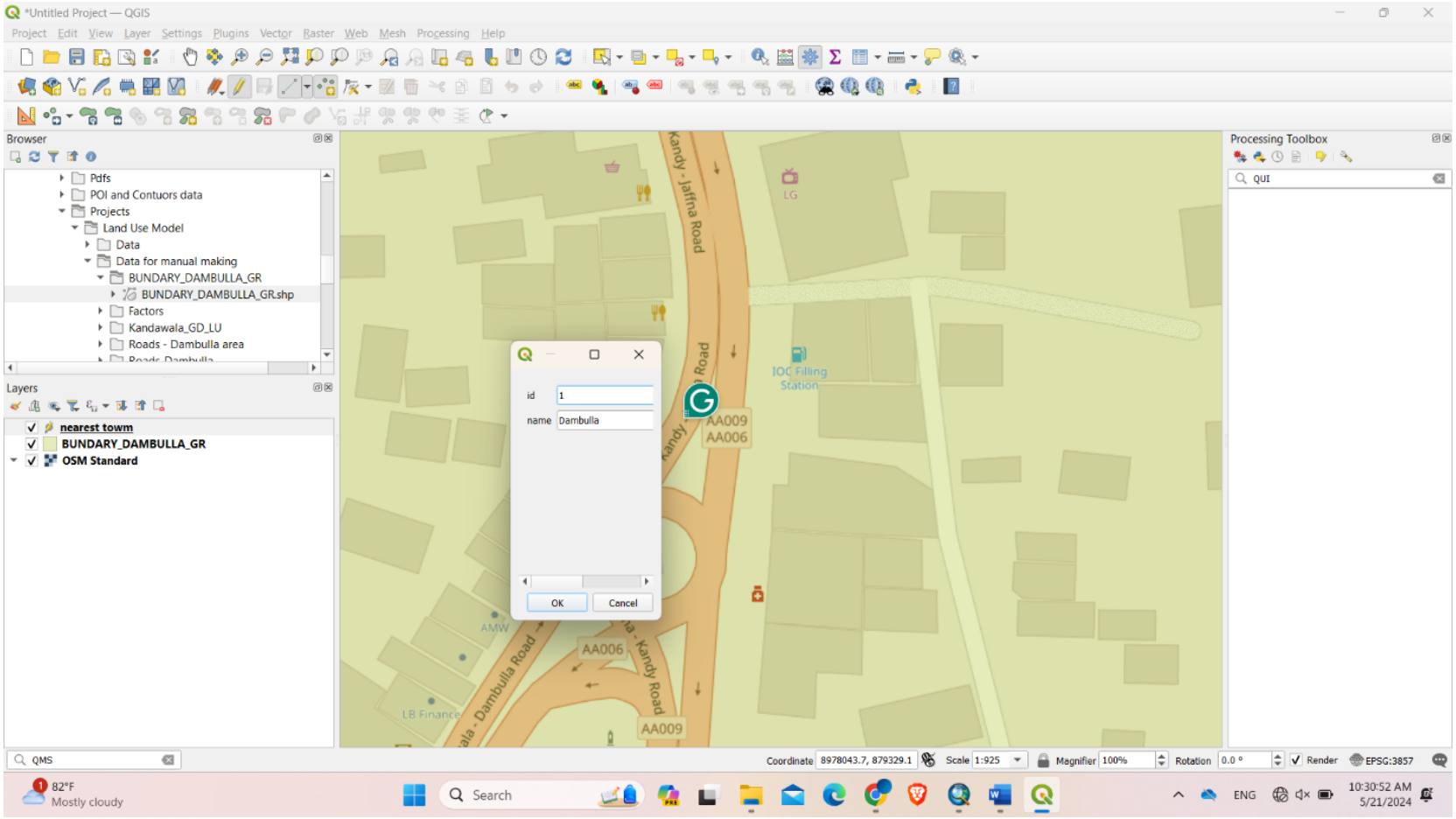
- Select the layer you want to digitize in the Layers Panel.
- Make sure the editing mode is enabled by clicking the "**Toggle Editing**" button in the Digitizing toolbar.



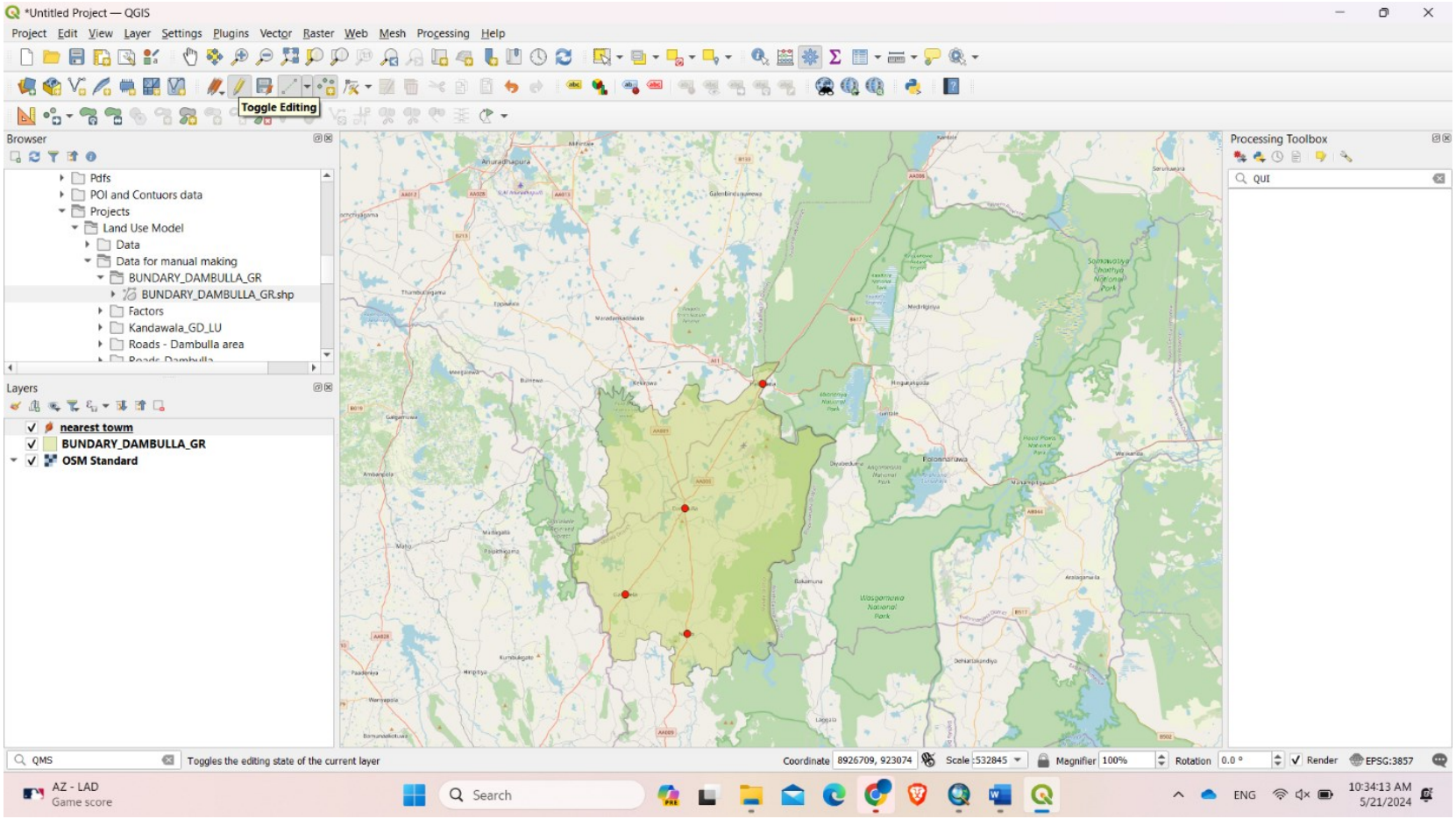
Choose the appropriate digitizing tool from the Digitizing toolbar.



- Start digitizing by clicking on the map canvas to create points.
- After clicking on a point, fill in attribute values for each feature using the attribute table.



Here are the added points according to the above way.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Land Use Model
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BUNDARY_DAMBULLA_GR.shp
Factors
Kandawala_GD_LU
Roads - Dambulla area
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Processing Toolbox
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Rotation 0.0 °
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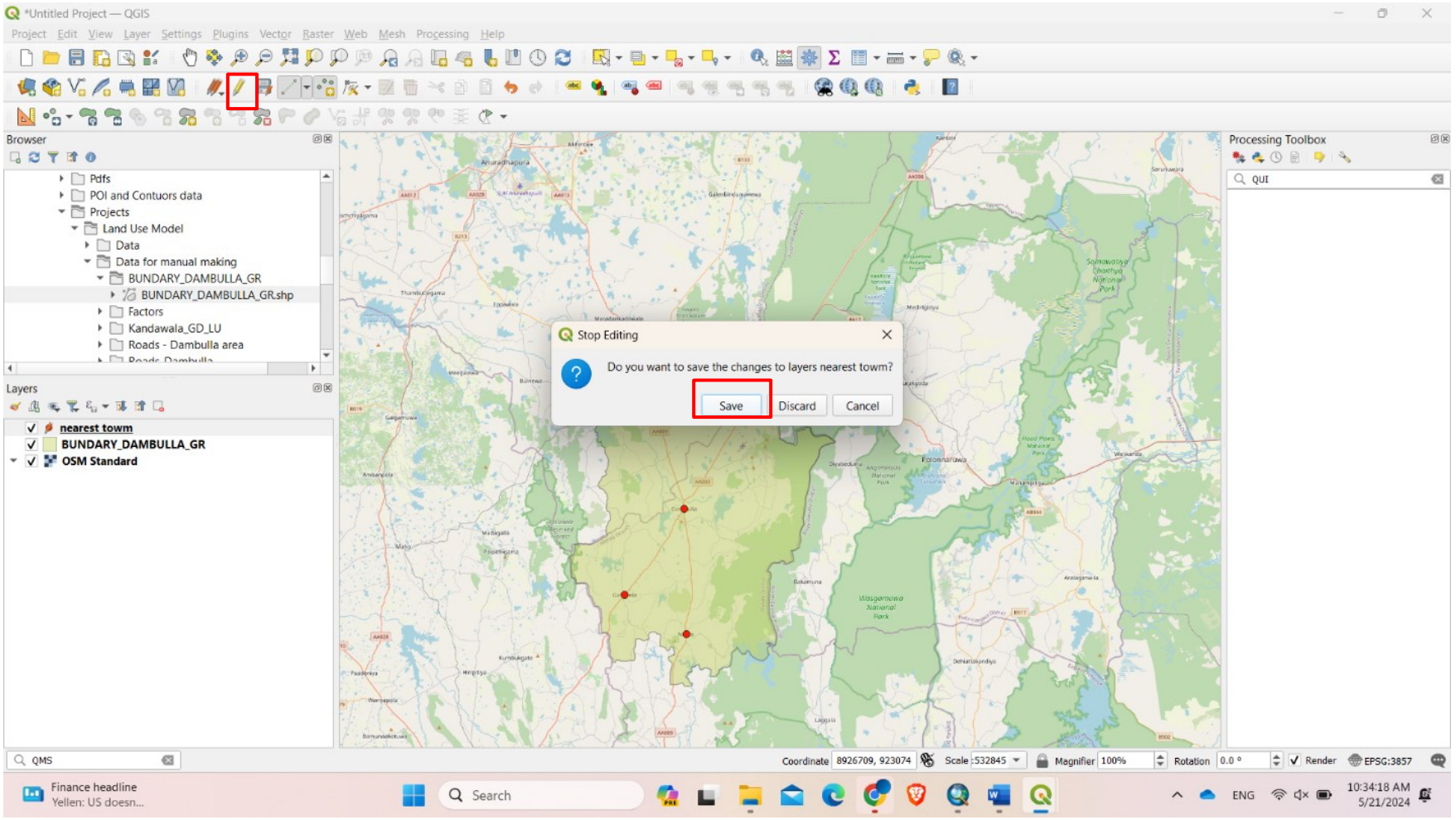
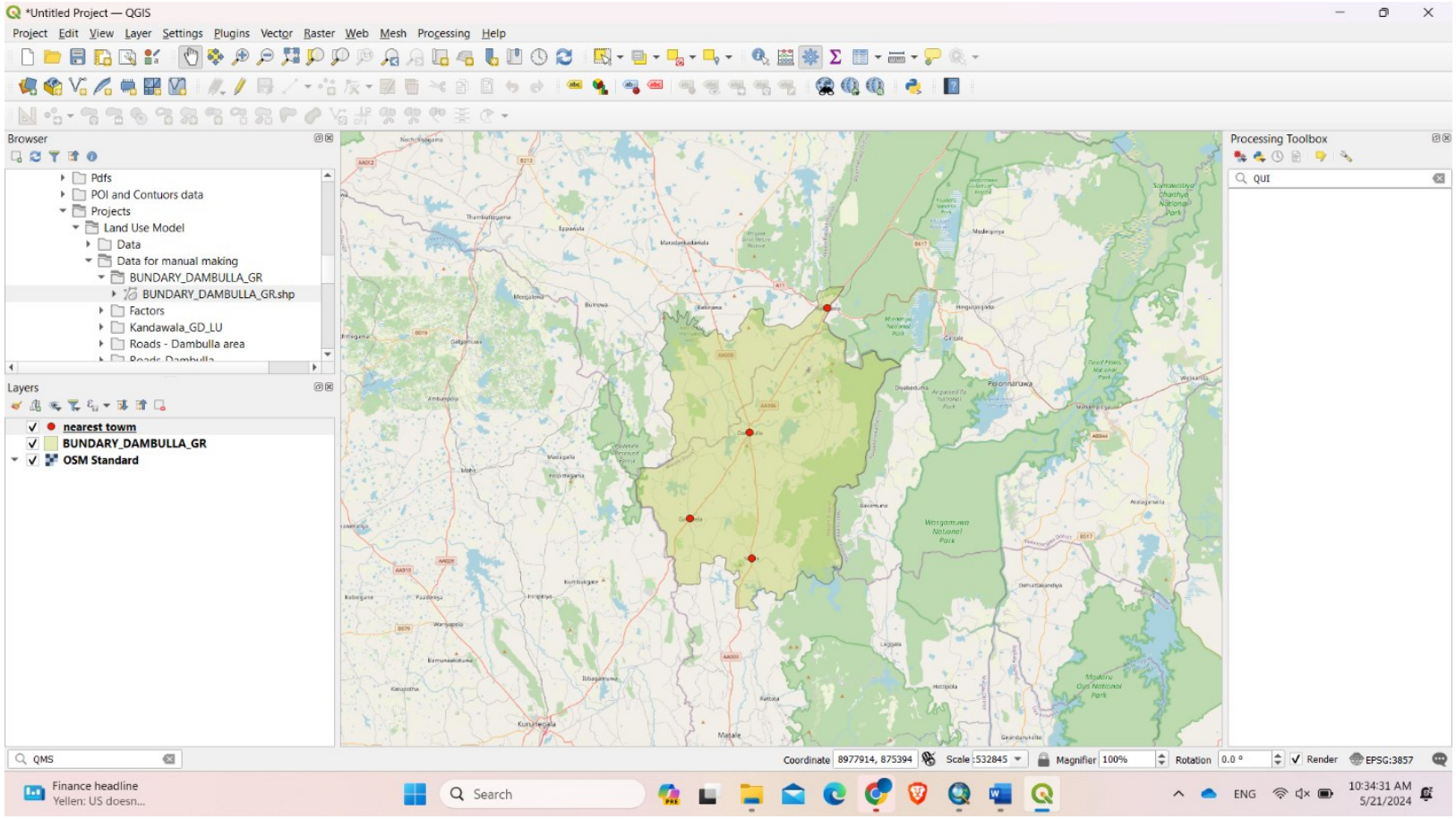
5/21/2024

Save your edits by clicking the "**Save Edits**" button in the Digitizing toolbar. Then click on "**Save**".



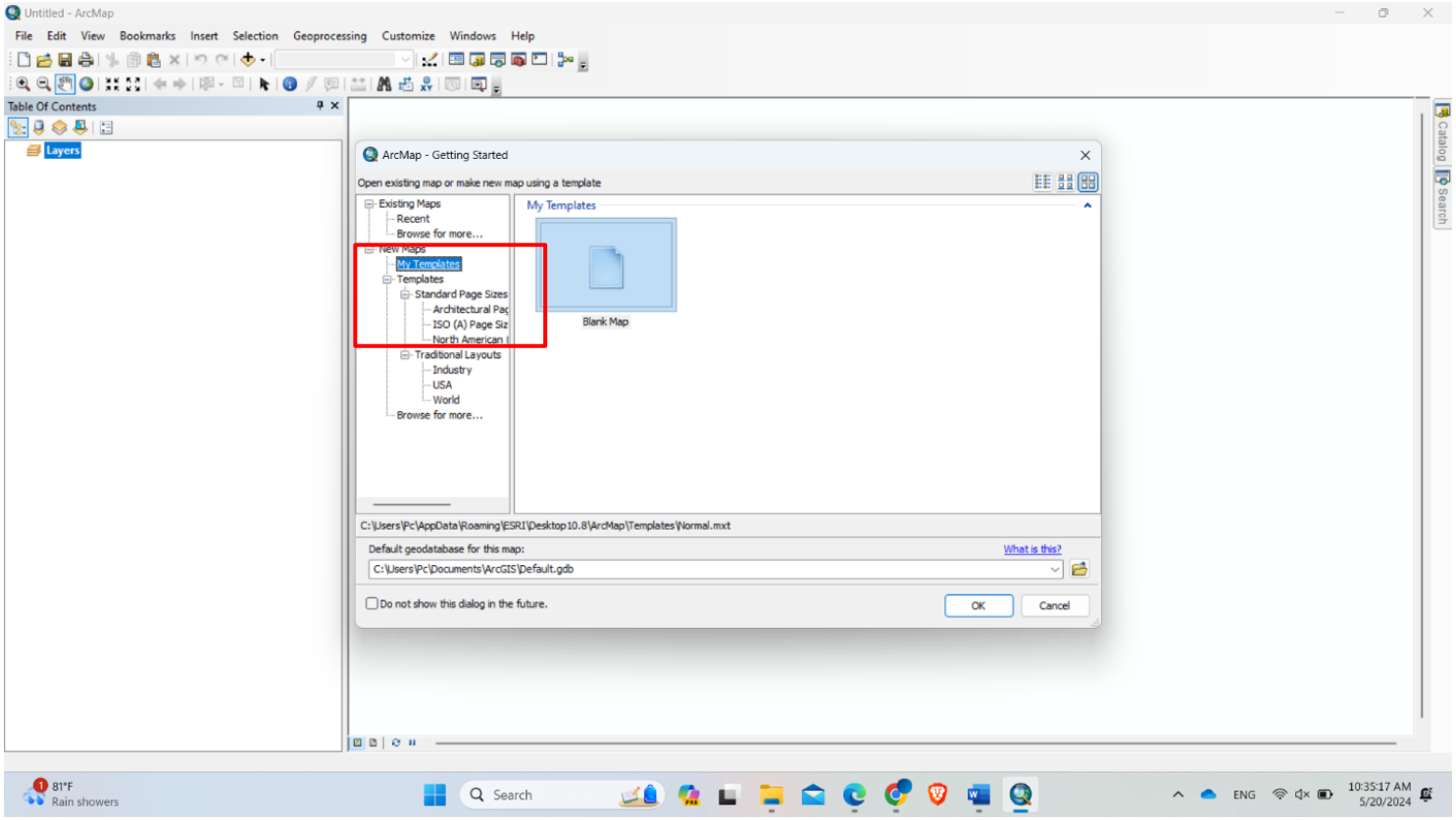
You've created a shapefile, digitized features, and added a base map in QGIS.



We will utilize ArcMap software for this task because it simplifies the process of calculating Euclidean distances to the nearest town centers. However, for other components of our analysis, such as point digitization, we will use QGIS. Using QGIS can't make an Euclidean distance map like the land use layer, so we will use ArcMap Software.

6. Open ArcMap

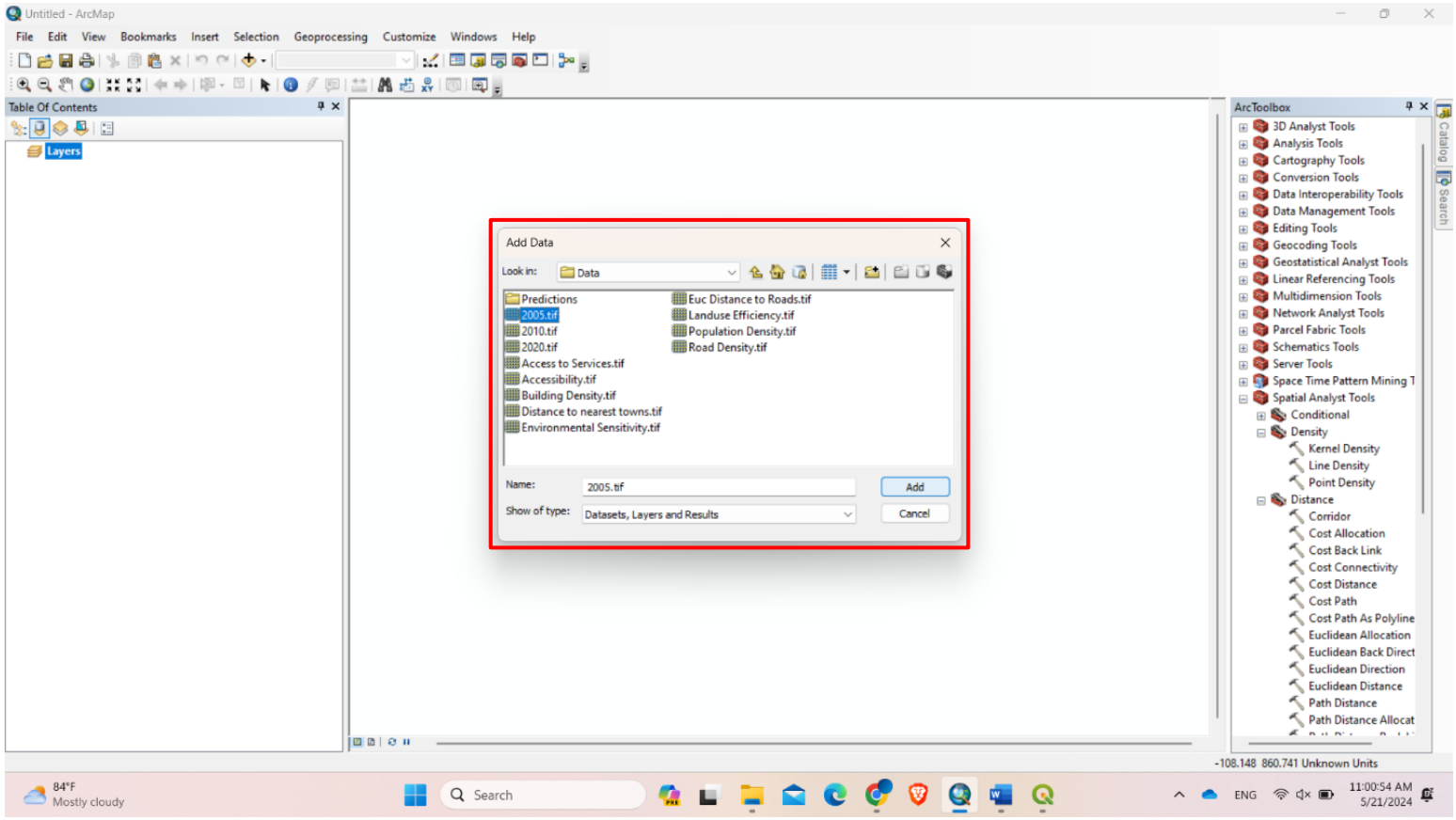
Launch ArcMap on your computer and open a new or existing project.

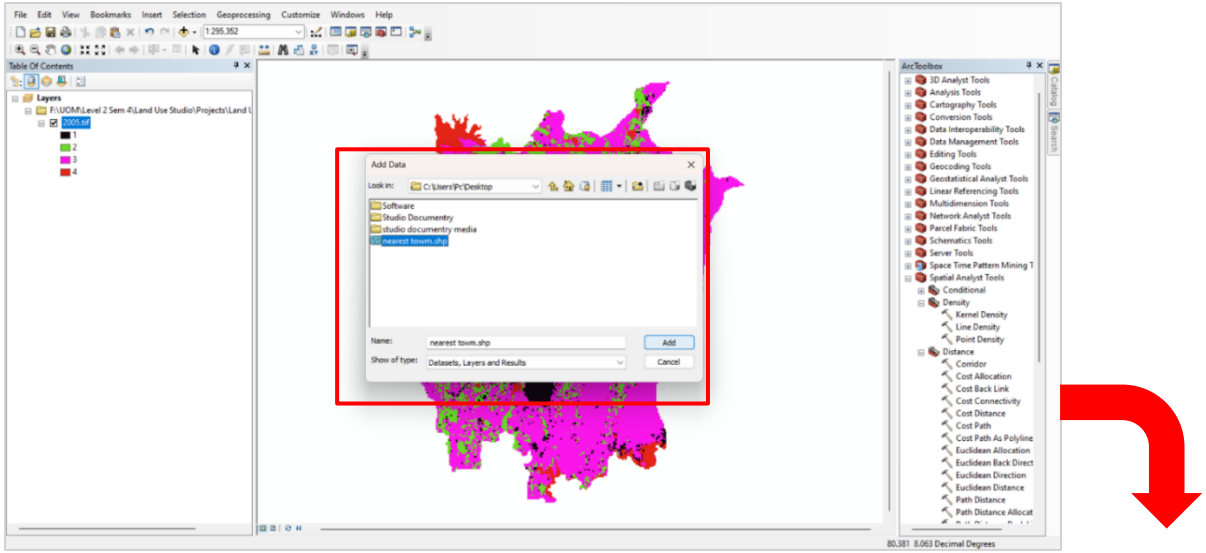


7. Add Shapefiles to the Map

- Go to **File > Add Data > Add Data**

- Navigate to and select your shapefiles for the town centers and land use layers. (The 2005 land use raster layer is needed because the raster file that is being created now wants to follow same the pixel size of the land use layer)
- Click “**Add**” to load them into your map. In this way, we import the shapefile previously prepared using QGIS into ArcMap.

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Cancel
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Cartography Tools
Conversion Tools
Data Interoperability Tools
Data Management Tools
Editing Tools
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Geostatistical Analyst Tools
Linear Referencing Tools
Multidimension Tools
Network Analyst Tools
Parcel Fabric Tools
Schematics Tools
Server Tools
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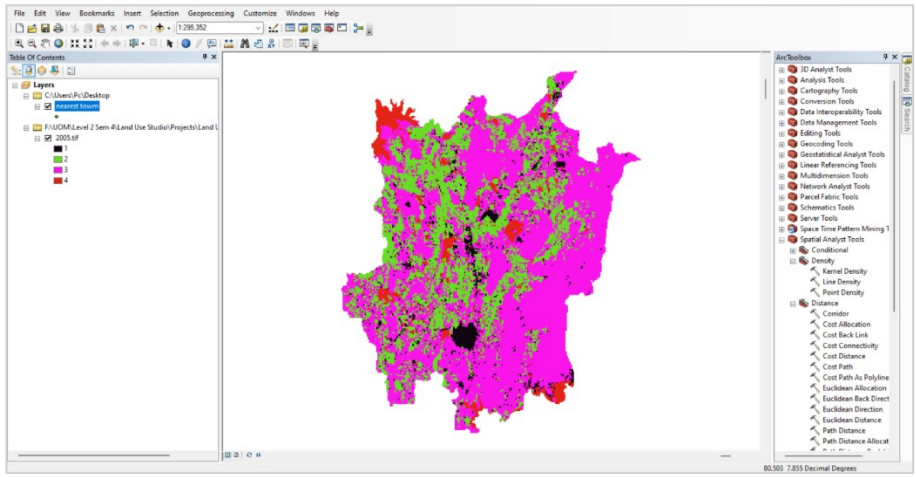
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Data Management Tools
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Geocoding Tools
Geostatistical Analyst Tools
Linear Referencing Tools
Multidimension Tools
Network Analyst Tools
Parcel Fabric Tools
Schematics Tools
Server Tools
Space Time Pattern Mining T
Spatial Analyst Tools
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Point Density
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Cost Allocation
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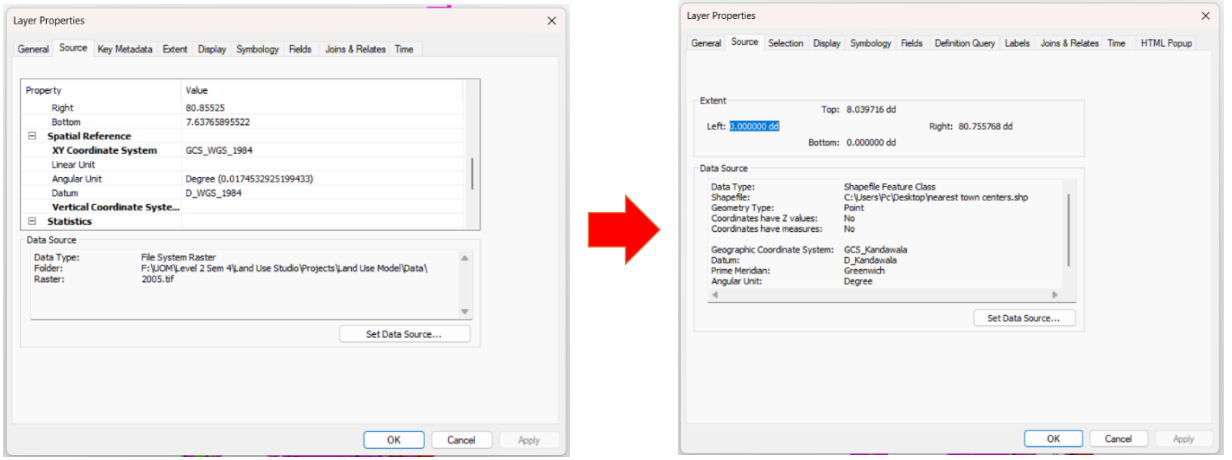
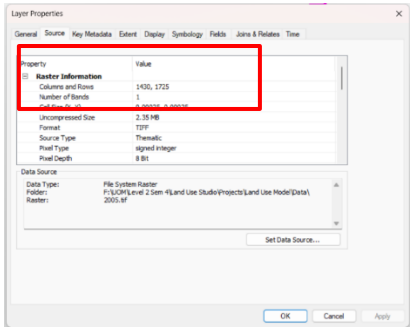
Euclidean Allocation
Euclidean Back Direct
Euclidean Direction
Euclidean Distance
Path Distance
Path Distance Allocat
80.503 7.855 Decimal Degrees

8. Ensure Consistent Coordinate Systems

- First, make sure that all your layers (Town centers layer and Land use layer) have the same coordinate system.
- Right-click each layer in the Table of Contents, select "**Properties**," then go to the "**Source**" tab to check the coordinate system.



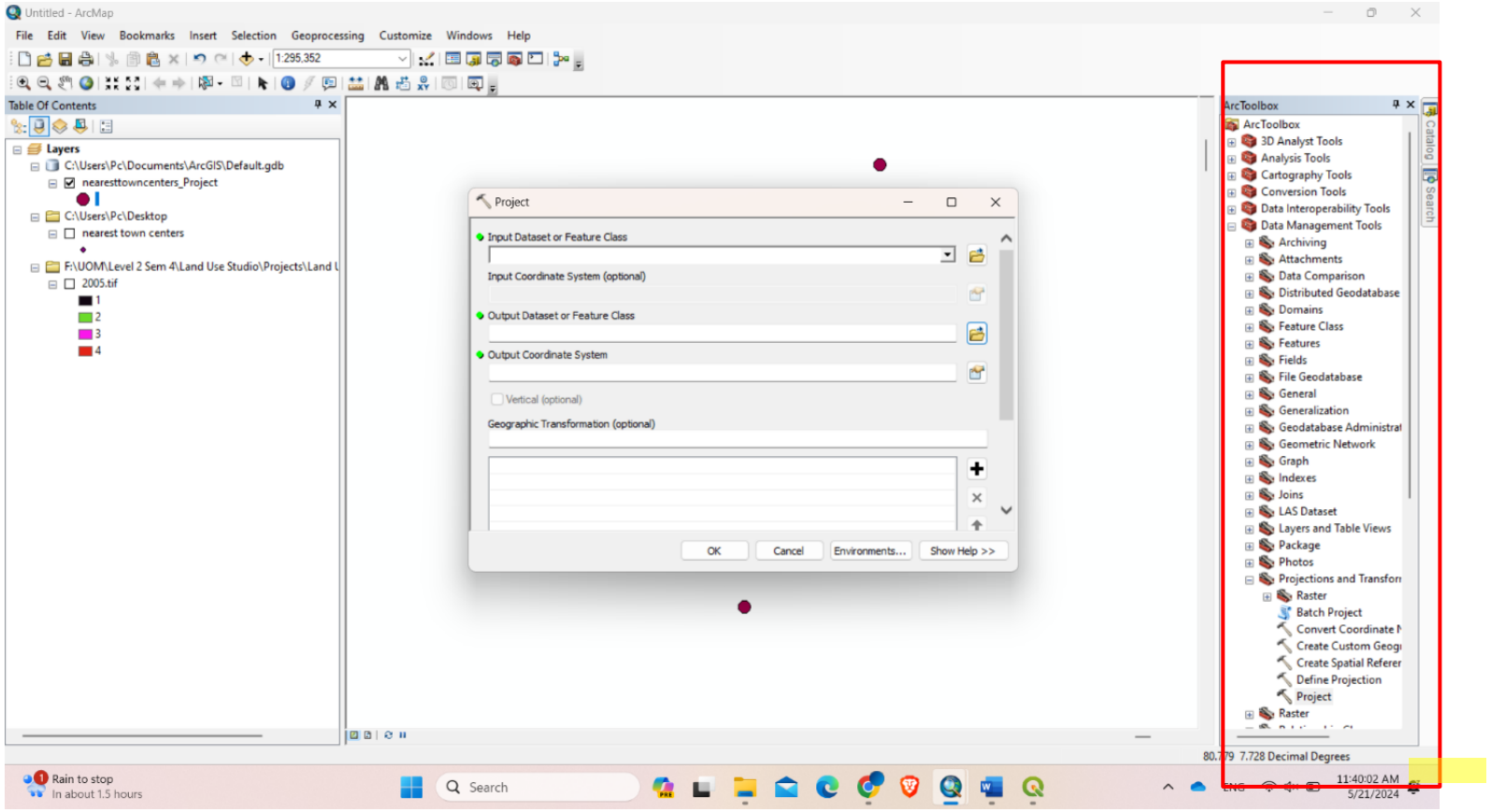
After that, checked and noted the pixel size and rows columns of the 2005 Land use raster file.



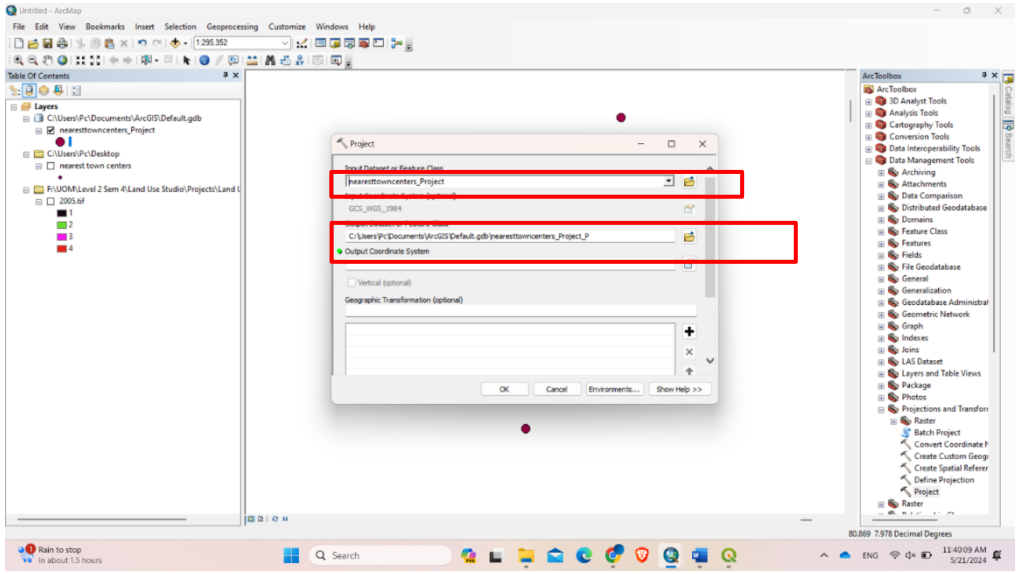
Upon examination, I observed discrepancies in the coordinate system of the town center file.

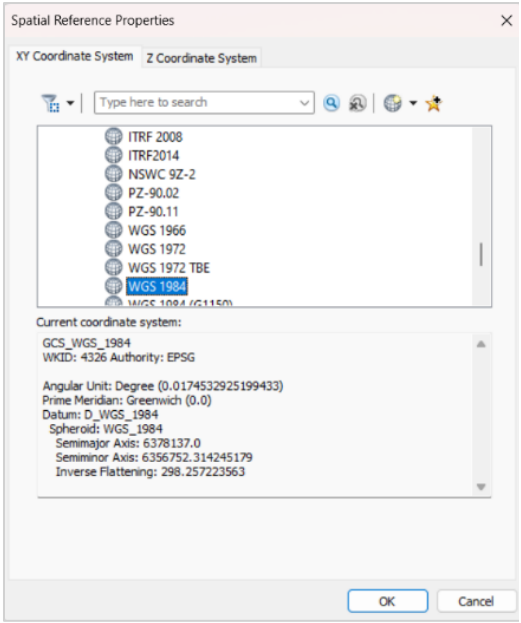
9. Project (.shp) file to the same coordinate system

- Consequently, I utilized the "Project" tool to rectify the coordinate system of the Town center's file to match the desired one.
- If any layers have different coordinate systems, you need to project them to the same coordinate system. You can use the "Project" tool found under **Data Management Tools > Projections and Transformations > Project** on ArcToolBox.

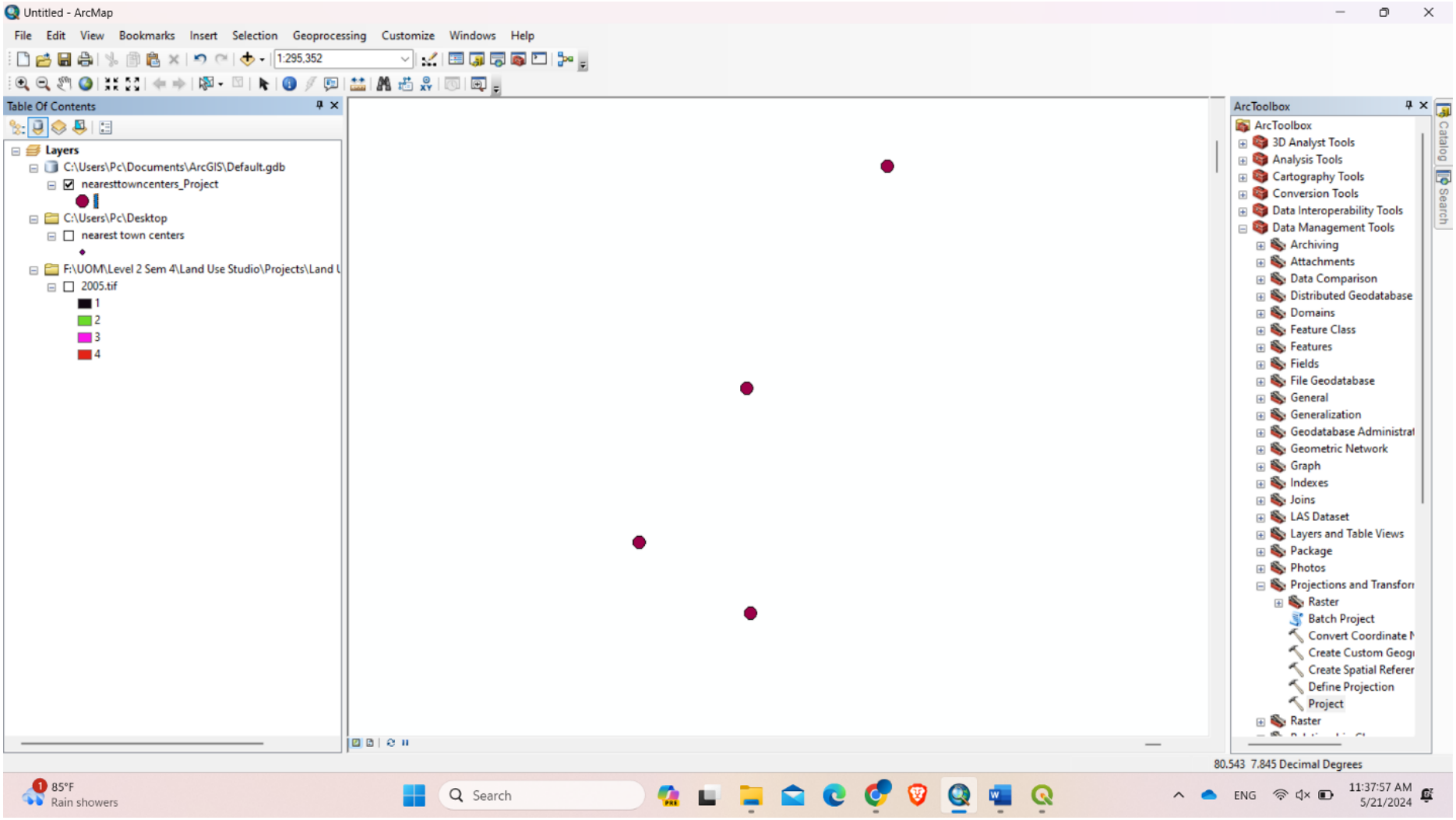


Select the projected town centers layer to the Input Dataset or feature class and select 2005 Land use raster layers' coordinate system to coordinate system.

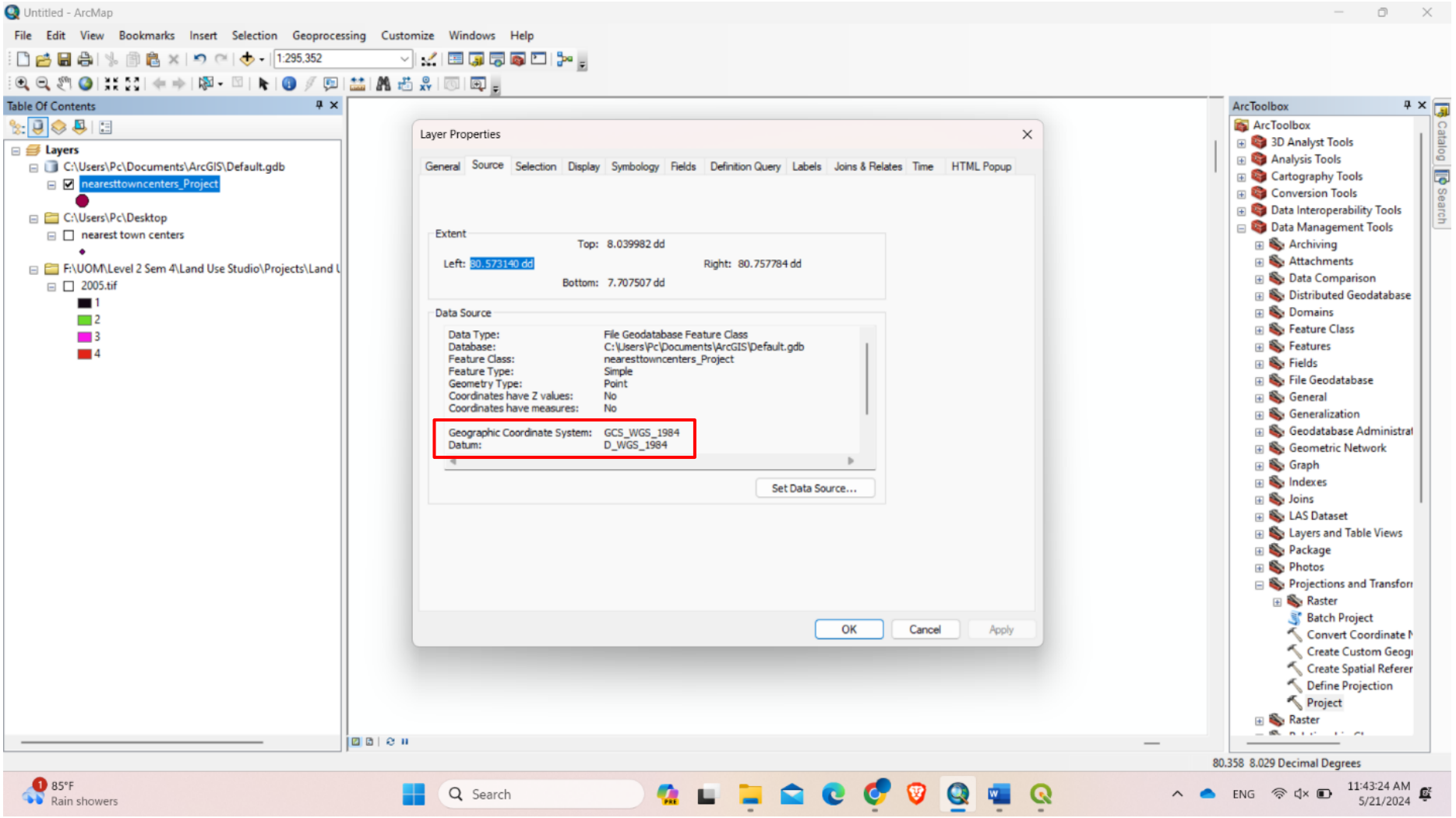




Now you can see the projected town centers file.

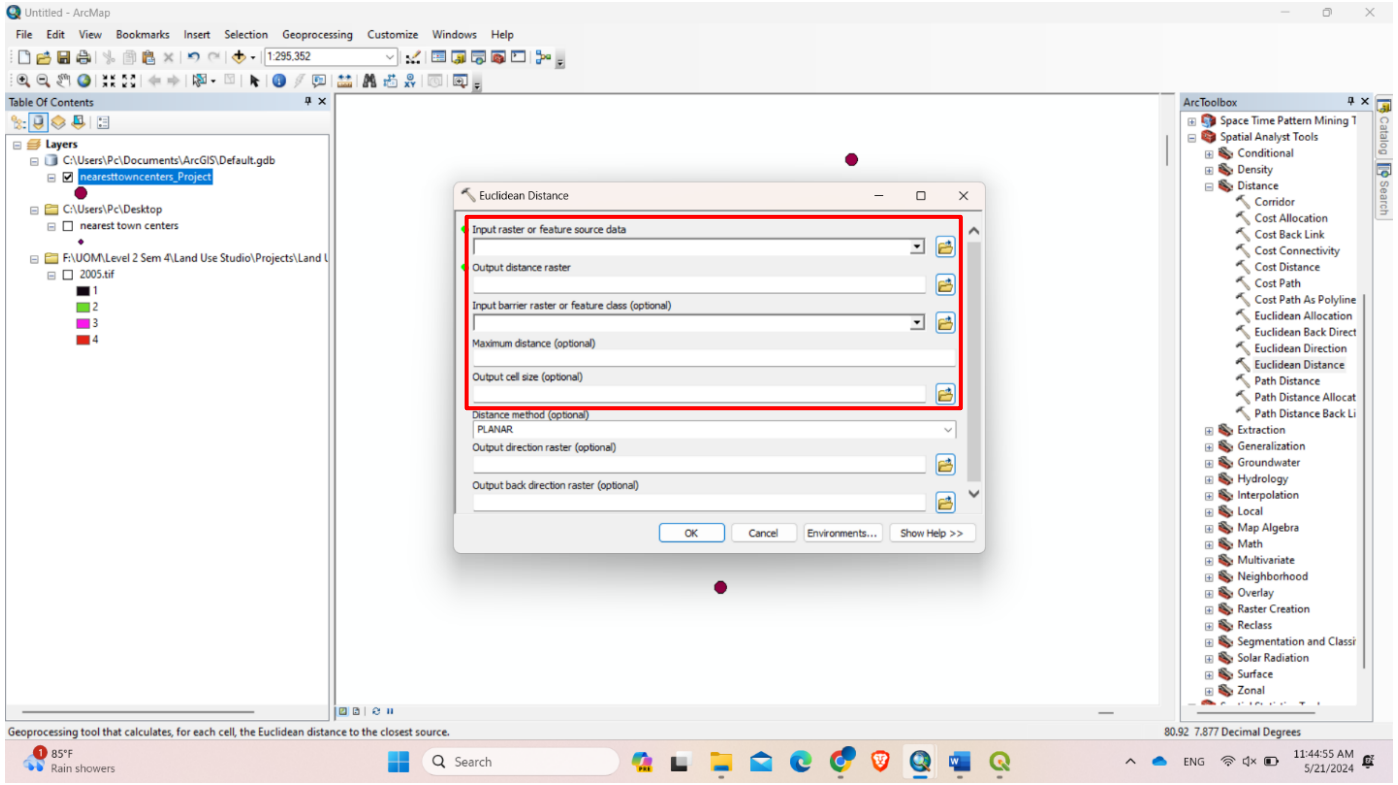


Once the project tool has finished running, check the coordinate system of the raster file.



10. Open the Euclidean Distance Tool

Go to **ArcToolbox > Spatial Analyst Tools > Distance > Euclidean Distance**.



Configure the Euclidean Distance Tool

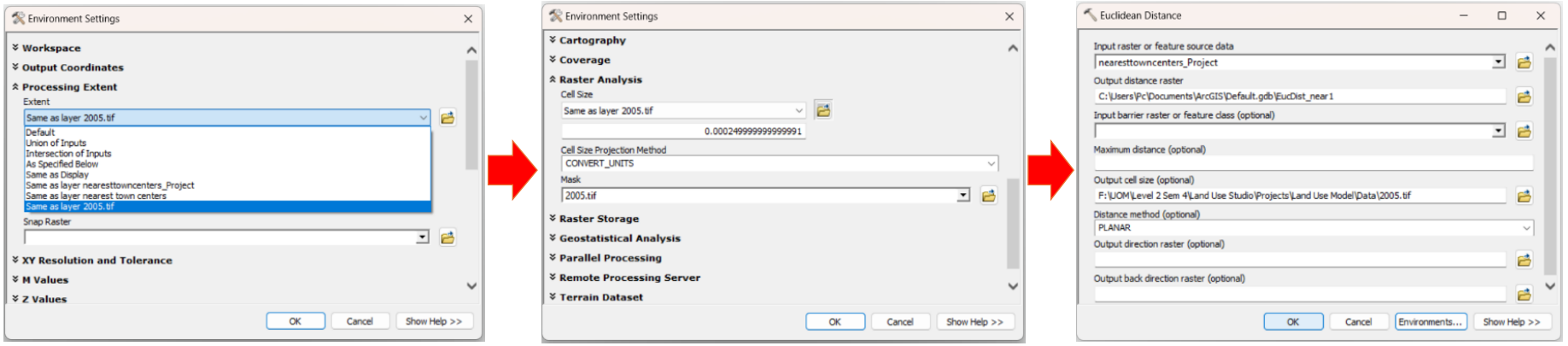
I. **Input raster or feature source data:** Select the town center point layer.
II. **Output distance raster:** Specify the location and name of the output raster file.
III. **Maximum distance (Optional):** Set a maximum distance limit if needed.
IV. **Output cell size:** Ensure it matches the cell size set in the Environment Settings.

Set the Environment Settings

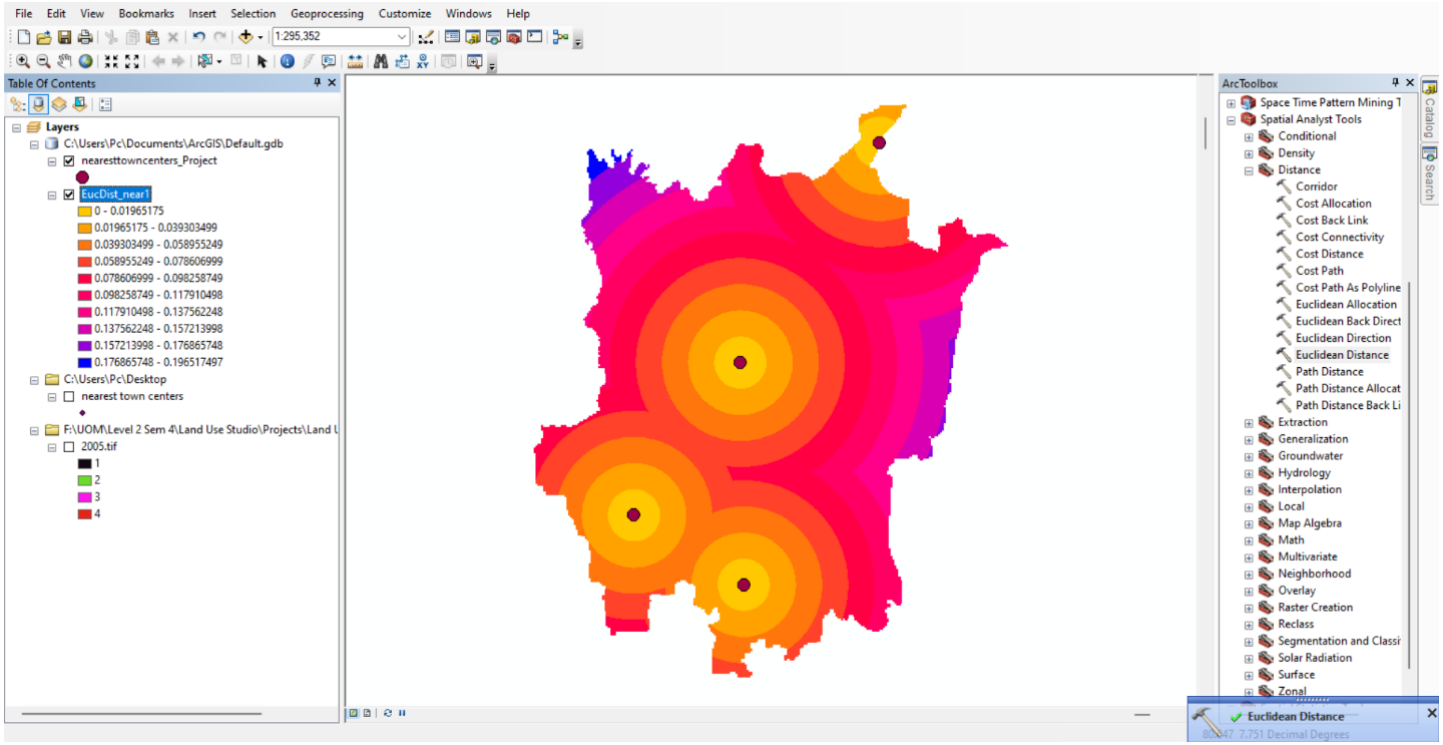
- Go to Environments.
- In the Environment Settings dialog box, set the following:
  - **Workspace:** Set the current and scratch workspace.
  - **Processing Extent:** Set to the same as your land use layer.
  - **Raster Analysis Settings:**

    Cell Size: Set the cell size (pixel size) to match the resolution of your land use layer.

    Mask: Set the mask to your land use layer to ensure the output raster matches the area of interest.



By following these steps, you will create an Euclidean distance raster map that shows the distances from each cell to the nearest town center, with the correct pixel size and dimensions matching the land use layer.


File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
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0.078606999 - 0.098258749
0.098258749 - 0.117910498
0.117910498 - 0.137562248
0.137562248 - 0.157213998
0.157213998 - 0.176865748
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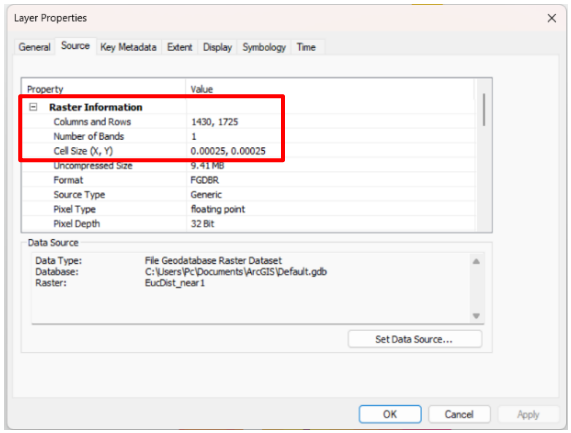
Groundwater
Hydrology
Interpolation
Local
Map Algebra
Math
Multivariate
Neighborhood
Overlay
Raster Creation
Reclass
Segmentation and Classi
Solar Radiation
Surface
Zonal
Euclidean Distance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Property Value
Raster Information
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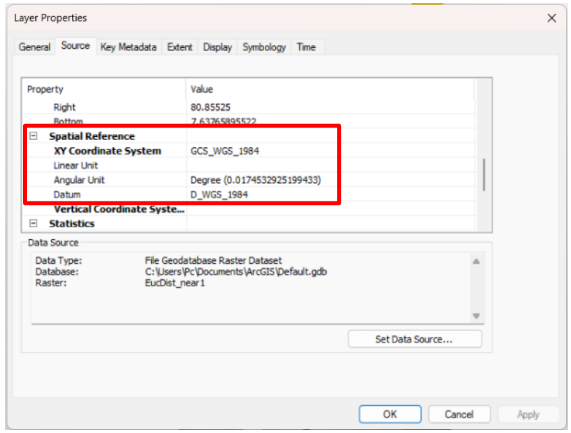
Number of Bands 1
Cell Size (X, Y) 0.00025, 0.00025
Uncompressed Size 9.41 MB
Format FGDBR
Source Type Generic
Pixel Type floating point
Pixel Depth 32 Bit
Data Source
Data Type: File Geodatabase Raster Dataset
Database: C:\Users\Pc\Documents\ArcGIS\Default.gdb
Raster: EucDist_near1
Set Data Source...
OK Cancel Apply


Layer Properties
General Source Key Metadata Extent Display Symbology Time
Property Value
Right 80.85525
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XY Coordinate System GCS_WGS_1984
Linear Unit
Angular Unit Degree (0.0174532925199433)
Datum D_WGS_1984
Vertical Coordinate Syste...
Statistics
Data Source
Data Type: File Geodatabase Raster Dataset
Database: C:\Users\Pc\Documents\ArcGIS\Default.gdb
Raster: EucDist_near1
Set Data Source...
OK Cancel Apply

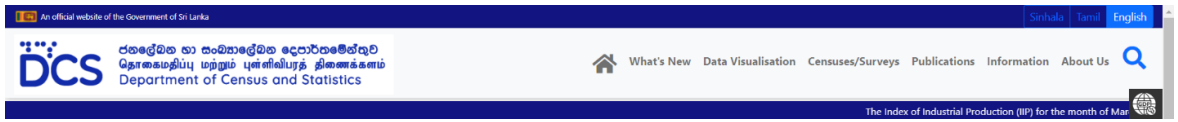
5. Population Density

Population density is a critical factor in land use prediction because it directly influences the demand for various types of land use. High population densities typically require more residential, commercial, and infrastructure development to support the needs of the population. This often leads to increased urbanization, with more land being allocated for housing, businesses, transportation networks, and public services. Consequently, urban planners and policymakers use population density data to forecast and plan for future land use needs, ensuring that adequate resources and spaces are available to accommodate growth.

To create this layer, first, gather population or population data on a secondary data source. Since data is available for DSDs, we divide our study area for DSDs as well.

01. Gather Data from the Department of Census website

Website: http://www.statistics.gov.lk/#gsc.tab=0



Go to Information>>District statistical handbook.

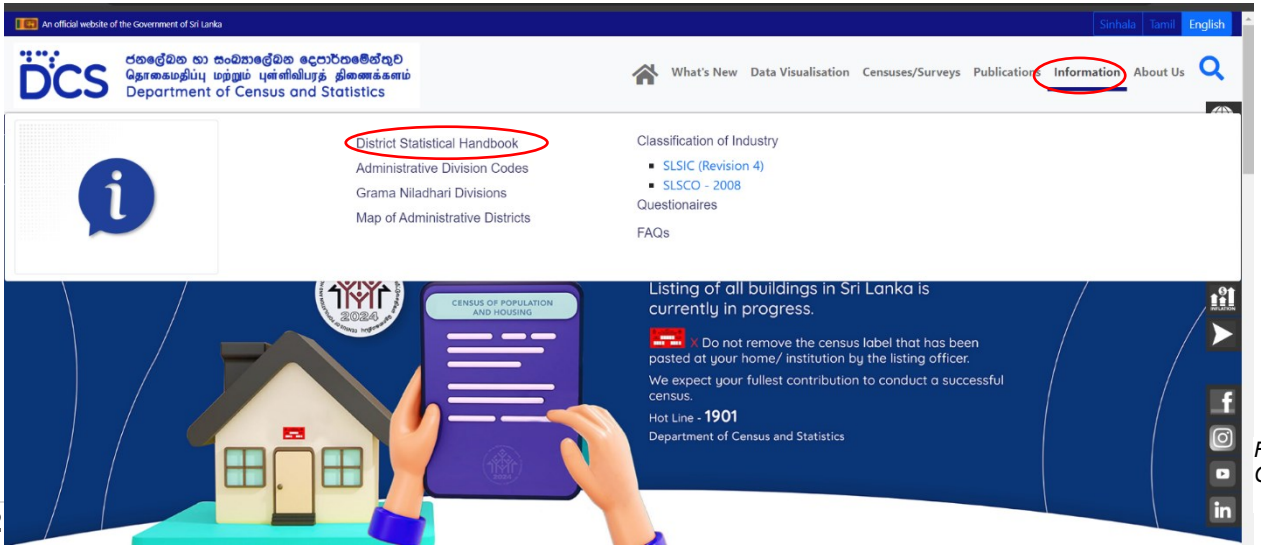
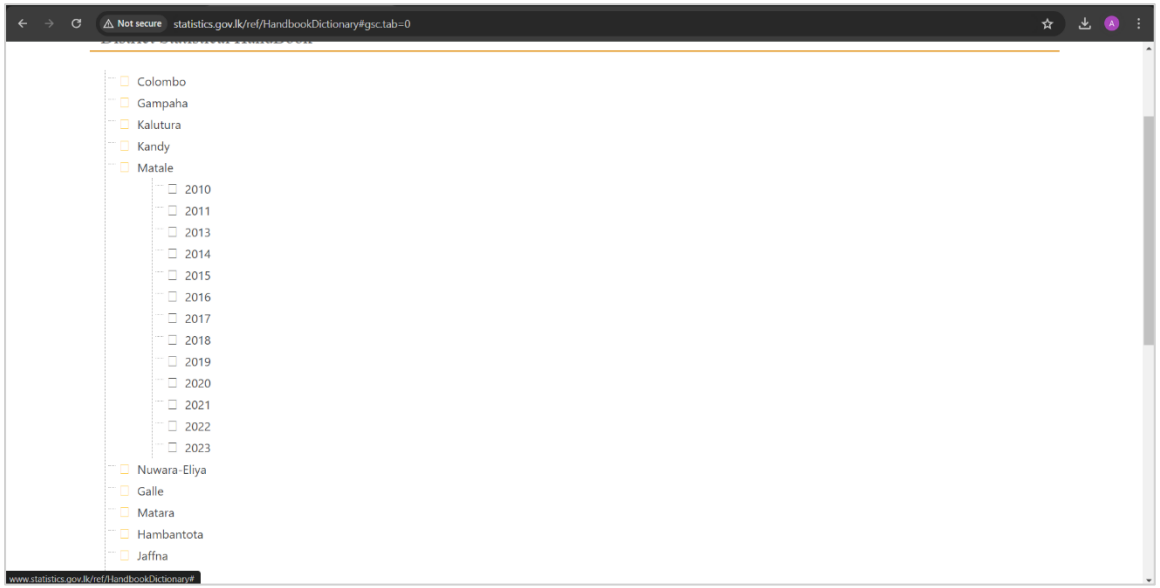
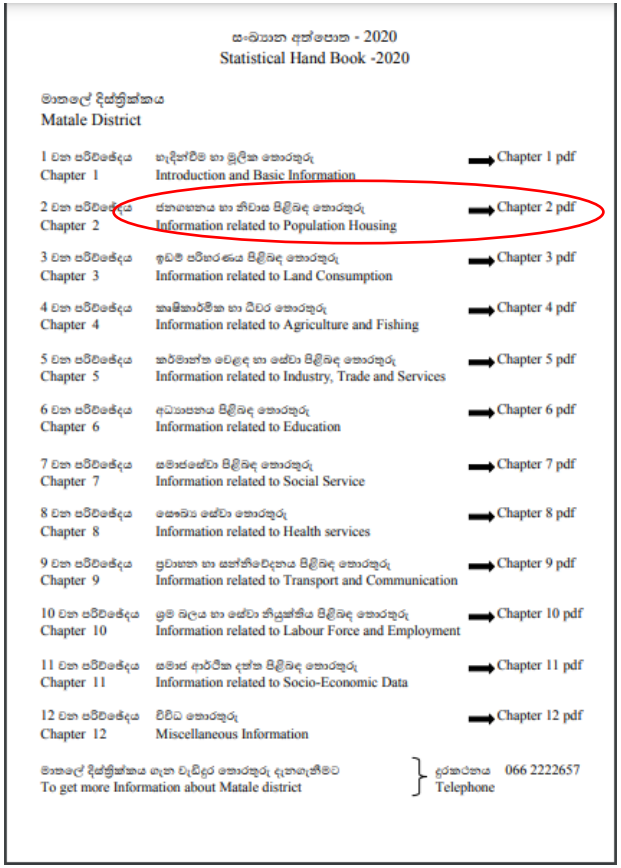


Figure 6 -The interface of the website of the Department of Census and Statistics

Extract the Name of the District and select the year in which we are going to collect data.



Then it provides this information.



සංඛ්‍යාන අත්පොත - 2020
Statistical Hand Book -2020

මාතලේ දිස්ත්‍රික්කය
Matale District

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8 වන පරිච්ඡේදය Chapter 8	සෞඛ්‍ය සේවා තොරතුරු Information related to Health services	Chapter 8 pdf
9 වන පරිච්ඡේදය Chapter 9	ප්‍රවාහන හා සන්නිවේදනය පිළිබඳ තොරතුරු Information related to Transport and Communication	Chapter 9 pdf
10 වන පරිච්ඡේදය Chapter 10	ශ්‍රම බලය හා සේවා නියුක්තිය පිළිබඳ තොරතුරු Information related to Labour Force and Employment	Chapter 10 pdf
11 වන පරිච්ඡේදය Chapter 11	සමාජ ආර්ථික දත්ත පිළිබඳ තොරතුරු Information related to Socio-Economic Data	Chapter 11 pdf
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මාතලේ දිස්ත්‍රික්කය ගැන වැඩිදුර තොරතුරු දැනගැනීමට
To get more Information about Matale district

දුරකථනය 066 2222657
Telephone

Now we have collected the Population density data which we are going to map out.

ප්‍රාදේශීය ලේකම් කොට්ඨාස හා අංශ අනුව ජනගහනය හා ජන ඝනත්වය - 2019

Population and Population Density by Sector and D.S.Division - 2019

වගුව Table : 2 .4

ප්‍රාදේශීය ලේකම් කොට්ඨාසය D.S. Division	ජනගහනය- Population			
	නාගරික Urban	ග්‍රාමීය Rural	වතු Estate	එකතුව Total
ගලේවෙල Galewela	-	75,322	182	75504
දඹුල්ල Dambulla	25,671	52,274	-	77945
නාඋළ Naula	-	29,130	-	29130
පල්ලේපොල Pallepola	-	31,262	609	31871
යටවත්ත Yatawatta	-	31,061	1,539	32600
මාතලේ Matale	38,251	41,599	852	80702
අඹන්ගහ කෝරළය Ambanganga Korale	-	14,066	2,797	16863
ලග්ගල පල්ලේගම Laggala Pallegama	-	17,058	158	17216
විල්ගමුව Wilgamuwa	-	31,794	-	31794
රත්තොට Rattota	-	47,430	7,929	55359
උකුවෙල Ukuwela	1,054	65,778	6,500	73332
එකතුව - Total	64976	436774	20566	522316

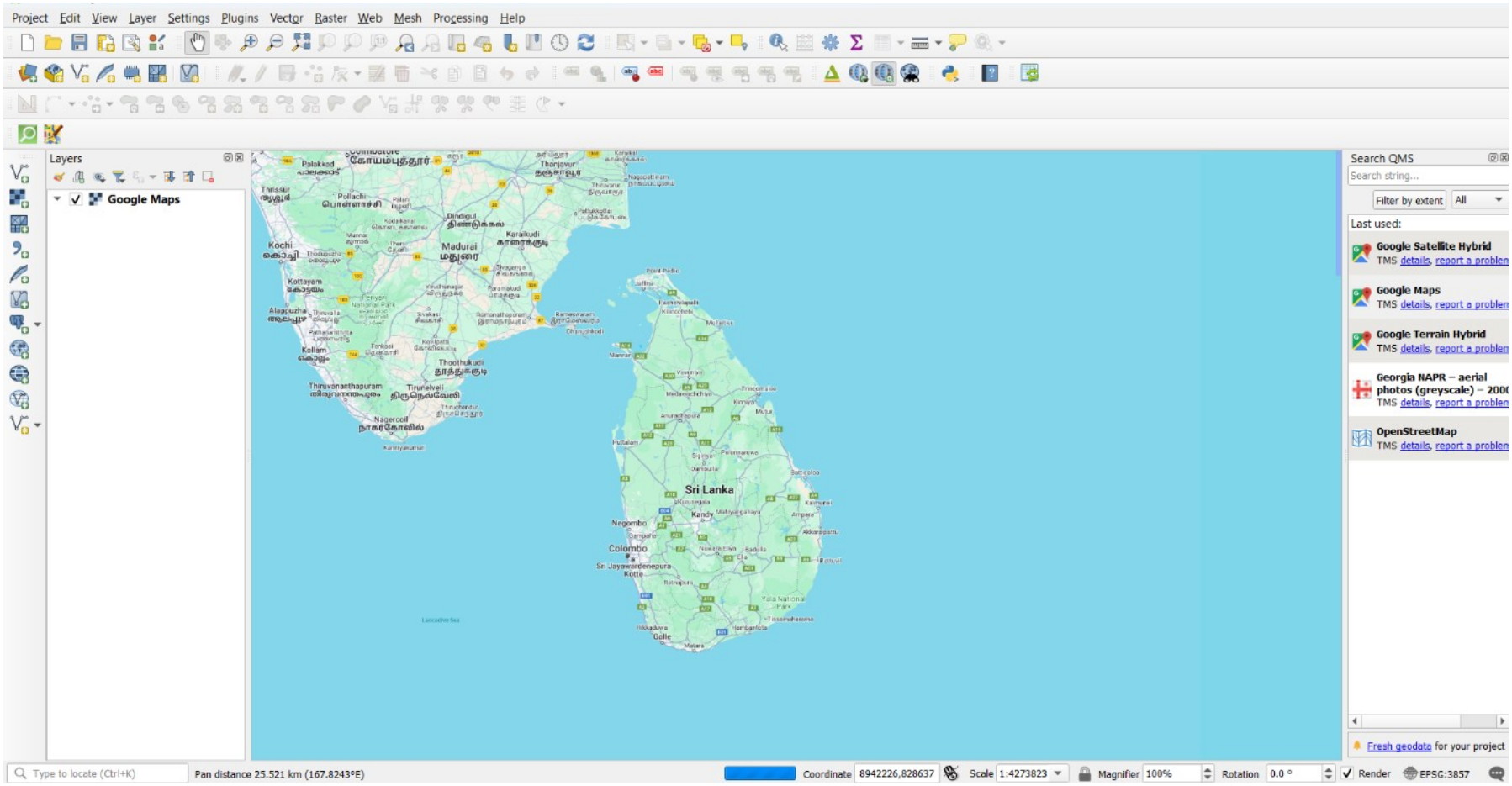
මූලාශ්‍රය - ජනලේඛන හා සංඛ්‍යාලේඛන දෙපාර්තමේන්තුව

Source -Department of Census and Statistics

Now that we have the data for the population density, we can create the population data layer.

02. Import population density data to QGIS

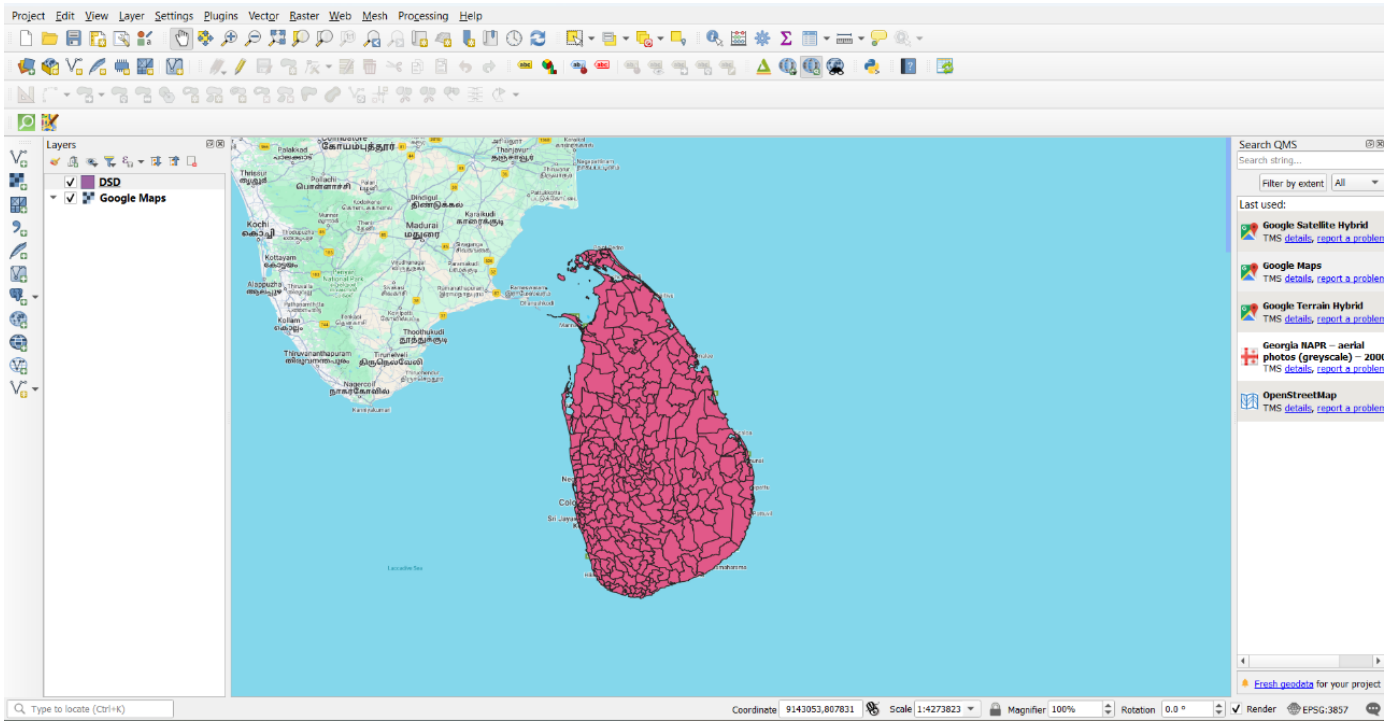
Open QGIS and add a base map to it.



Add a DSD (Divisional secretariat divisions) layer of Sri Lanka

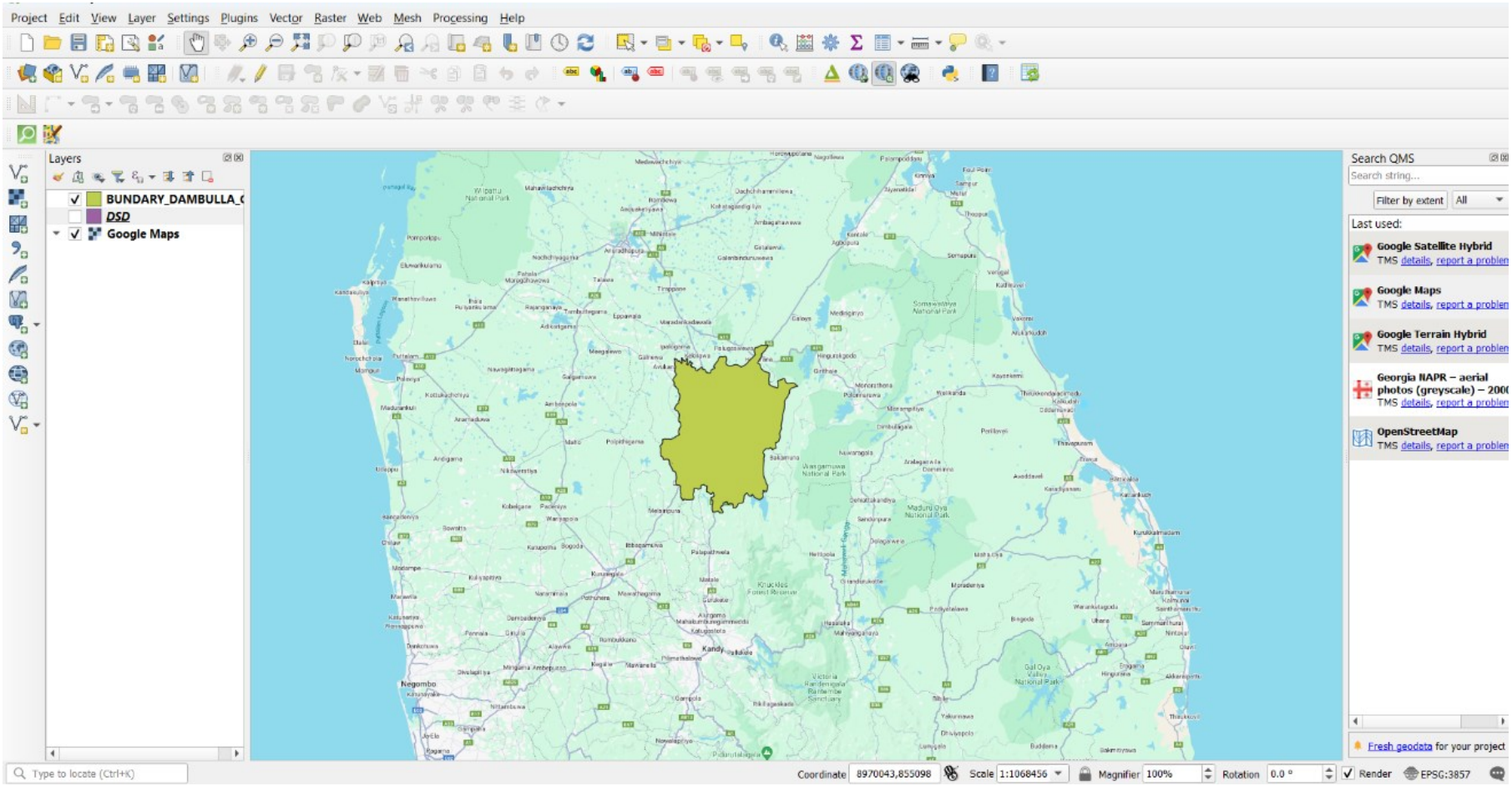
After clicking on “**Layer**”, the following window will open. Then, go to the relevant folder and select the vector file. Usually, a shape file consists of 6 other files. The file type you should choose to open here is the "**AutoCAD Shape Source**" file. As per the instructions, click on that layer, and after that click on “**Open**”. (For this you must have the relevant file.)

Go to **Layer > Add Layer > Add Vector Layer > Browse**



03. Add a layer to the study area.

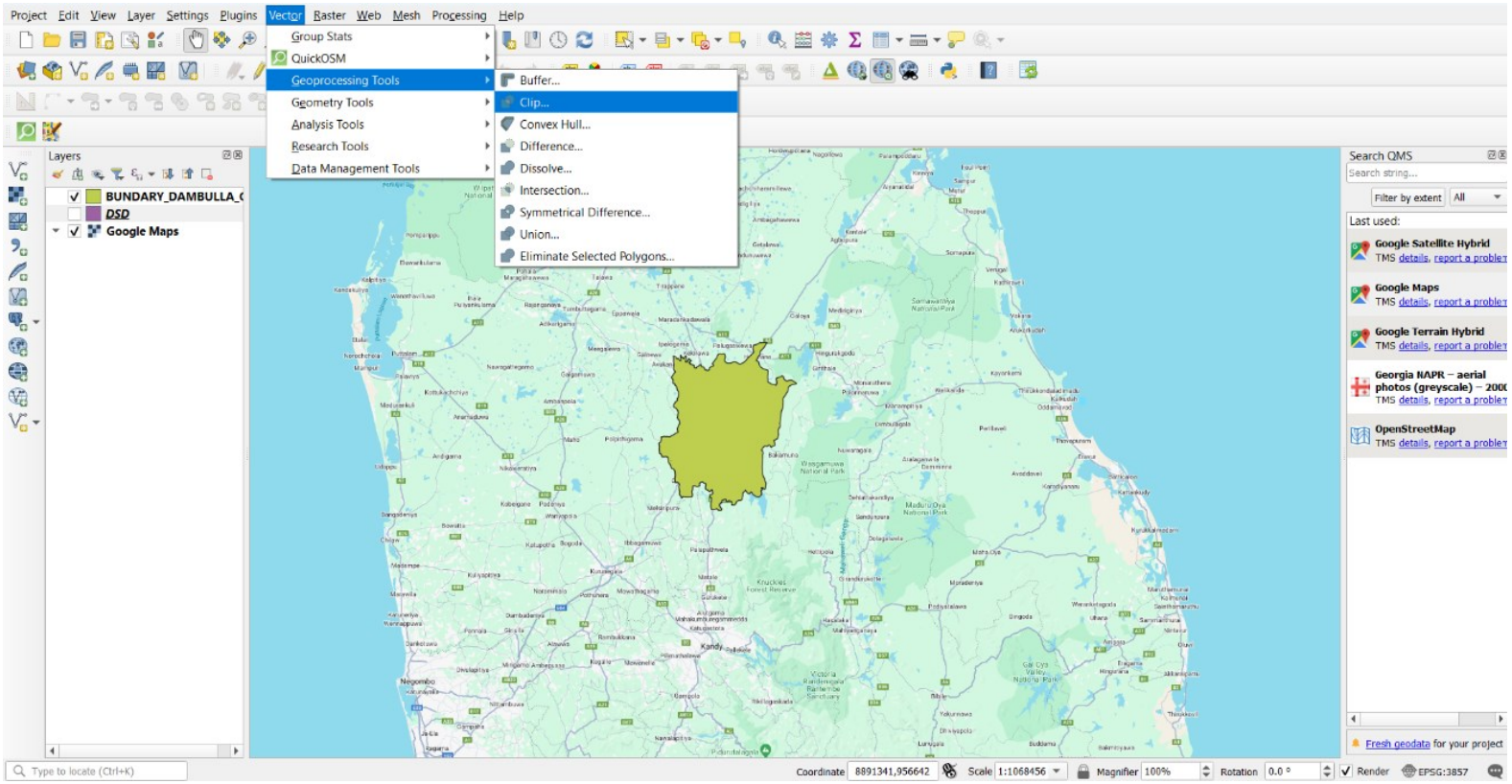
Go to **Layer > Add Layer > Add Vector Layer > Browse**



04. Run the Clip Tool.

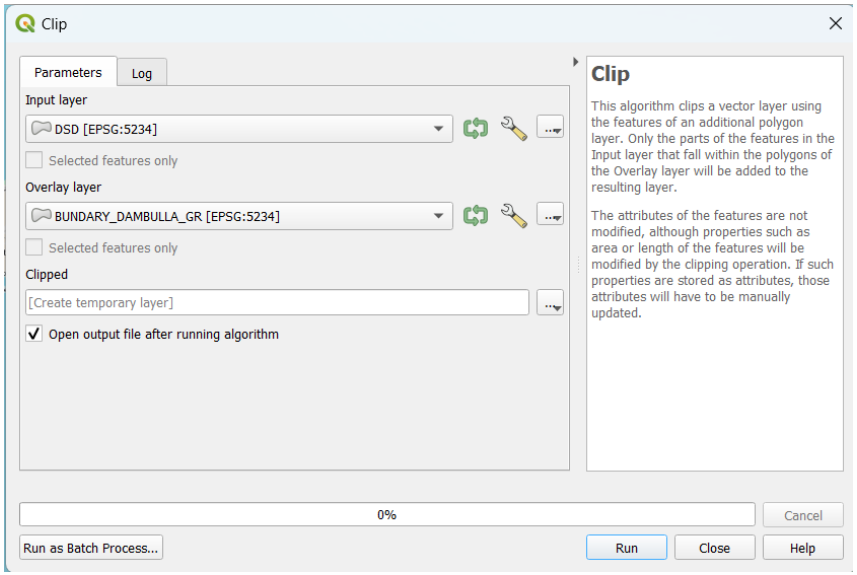
Clip the DSD layer and the Boundary layer of the Greater Dambulla.

Go to **Vector > Geoprocessing Tools > Clip**



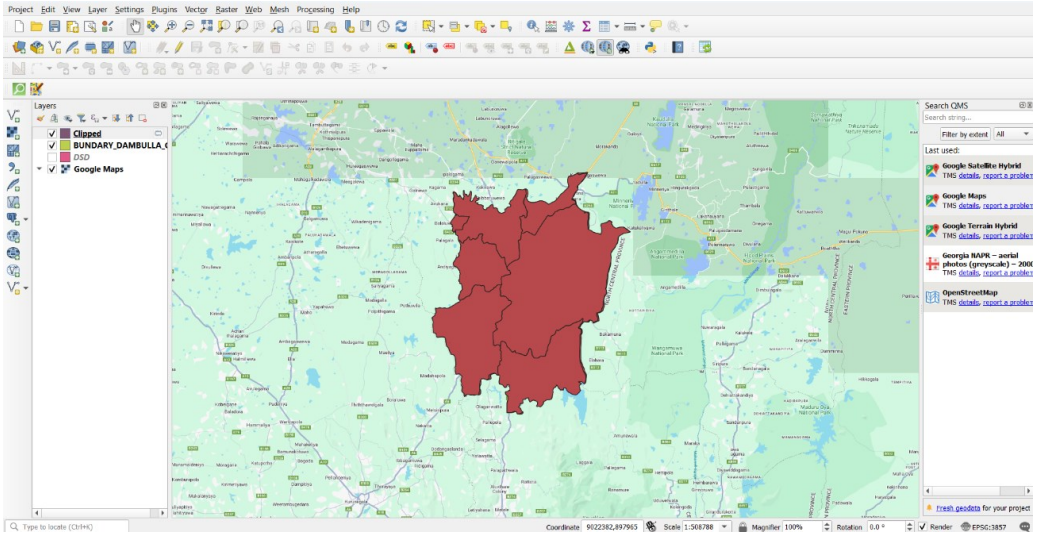
I. Select the DSD Layer as the Input layer.

II. Select the Boundary layer of the study area as the Overlay layer.



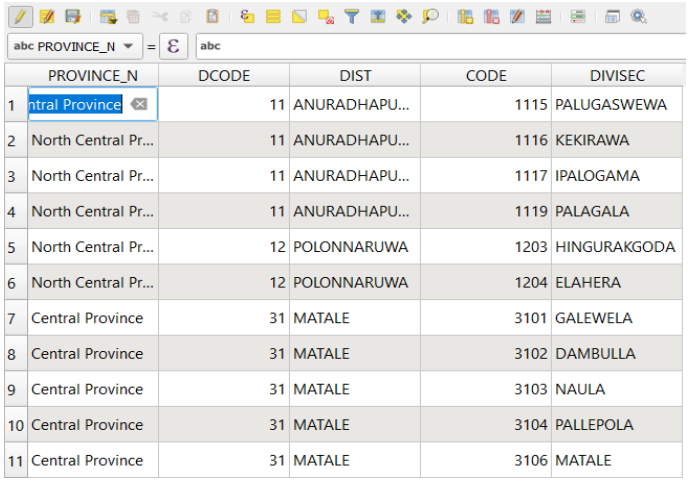
III. After setting the parameters, click "**Run**" to run the Clip tool. The tool will process the data and create a new clipped layer based on the boundary you provided.

This is the clipped output.



05. Create and update the Population density field

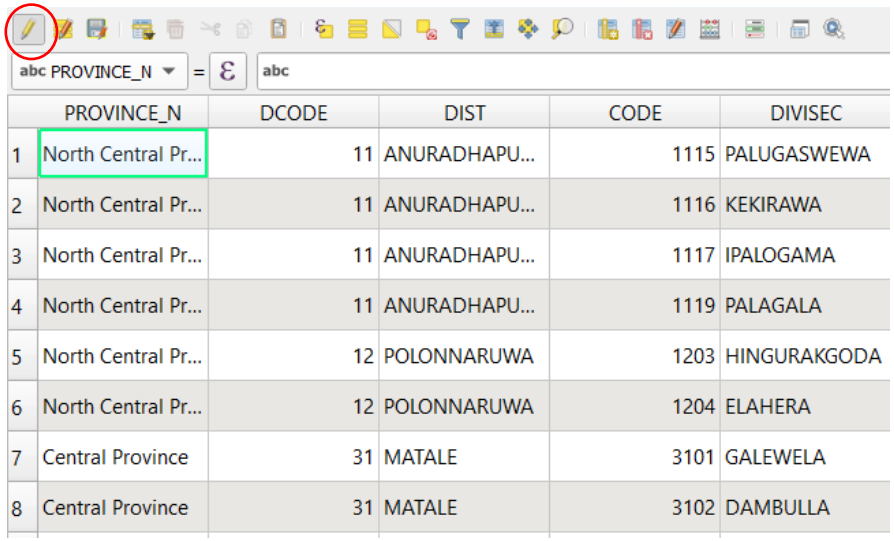
Open the attribute table of the layer. For that, **right-click on the layer > Open attribute table**



	PROVINCE_N	DCODE	DIST	CODE	DIVISEC
1	ntral Province	11	ANURADHAPU...	1115	PALUGASWEWA
2	North Central Pr...	11	ANURADHAPU...	1116	KEKIRAWA
3	North Central Pr...	11	ANURADHAPU...	1117	IPALOGAMA
4	North Central Pr...	11	ANURADHAPU...	1119	PALAGALA
5	North Central Pr...	12	POLONNARUWA	1203	HINGURAKGODA
6	North Central Pr...	12	POLONNARUWA	1204	ELAHERA
7	Central Province	31	MATALE	3101	GALEWELA
8	Central Province	31	MATALE	3102	DAMBULLA
9	Central Province	31	MATALE	3103	NAULA
10	Central Province	31	MATALE	3104	PALLEPOLA
11	Central Province	31	MATALE	3106	MATALE

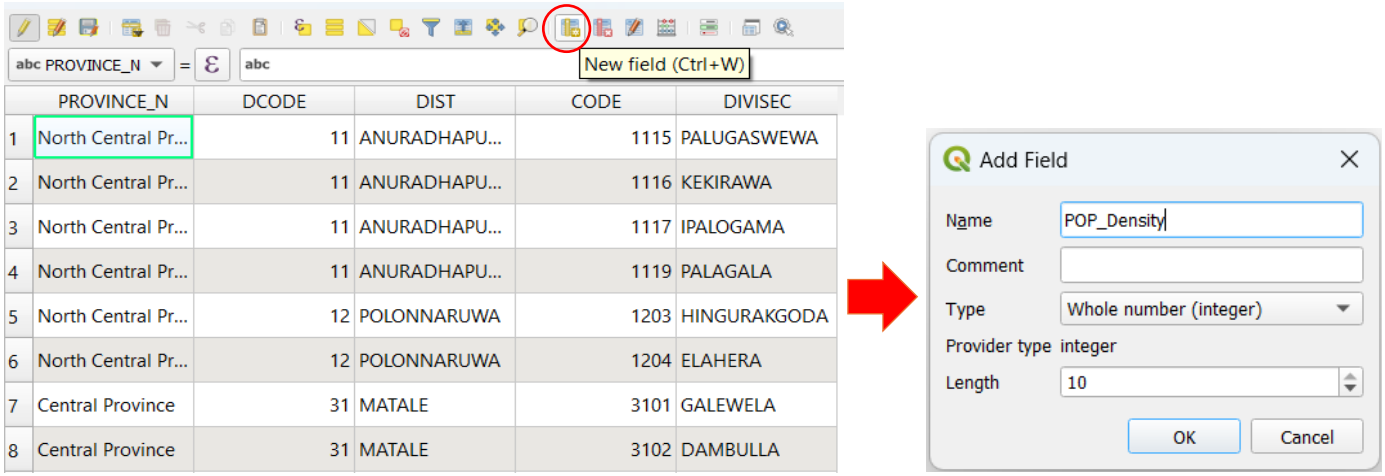
Add a new Field for Population Density.

For that, click on the **Toggle editing tool**.



	PROVINCE_N	DCODE	DIST	CODE	DIVISEC
1	North Central Pr...	11	ANURADHAPU...	1115	PALUGASWEWA
2	North Central Pr...	11	ANURADHAPU...	1116	KEKIRAWA
3	North Central Pr...	11	ANURADHAPU...	1117	IPALOGAMA
4	North Central Pr...	11	ANURADHAPU...	1119	PALAGALA
5	North Central Pr...	12	POLONNARUWA	1203	HINGURAKGODA
6	North Central Pr...	12	POLONNARUWA	1204	ELAHERA
7	Central Province	31	MATALE	3101	GALEWELA
8	Central Province	31	MATALE	3102	DAMBULLA

Add a new field as follows. Then you can see the menu like below you can enter the Field name and adjust the length of field characters.



	PROVINCE_N	DCODE	DIST	CODE	DIVISEC
1	North Central Pr...	11	ANURADHAPU...	1115	PALUGASWEWA
2	North Central Pr...	11	ANURADHAPU...	1116	KEKIRAWA
3	North Central Pr...	11	ANURADHAPU...	1117	IPALOGAMA
4	North Central Pr...	11	ANURADHAPU...	1119	PALAGALA
5	North Central Pr...	12	POLONNARUWA	1203	HINGURAKGODA
6	North Central Pr...	12	POLONNARUWA	1204	ELAHERA
7	Central Province	31	MATALE	3101	GALEWELA
8	Central Province	31	MATALE	3102	DAMBULLA

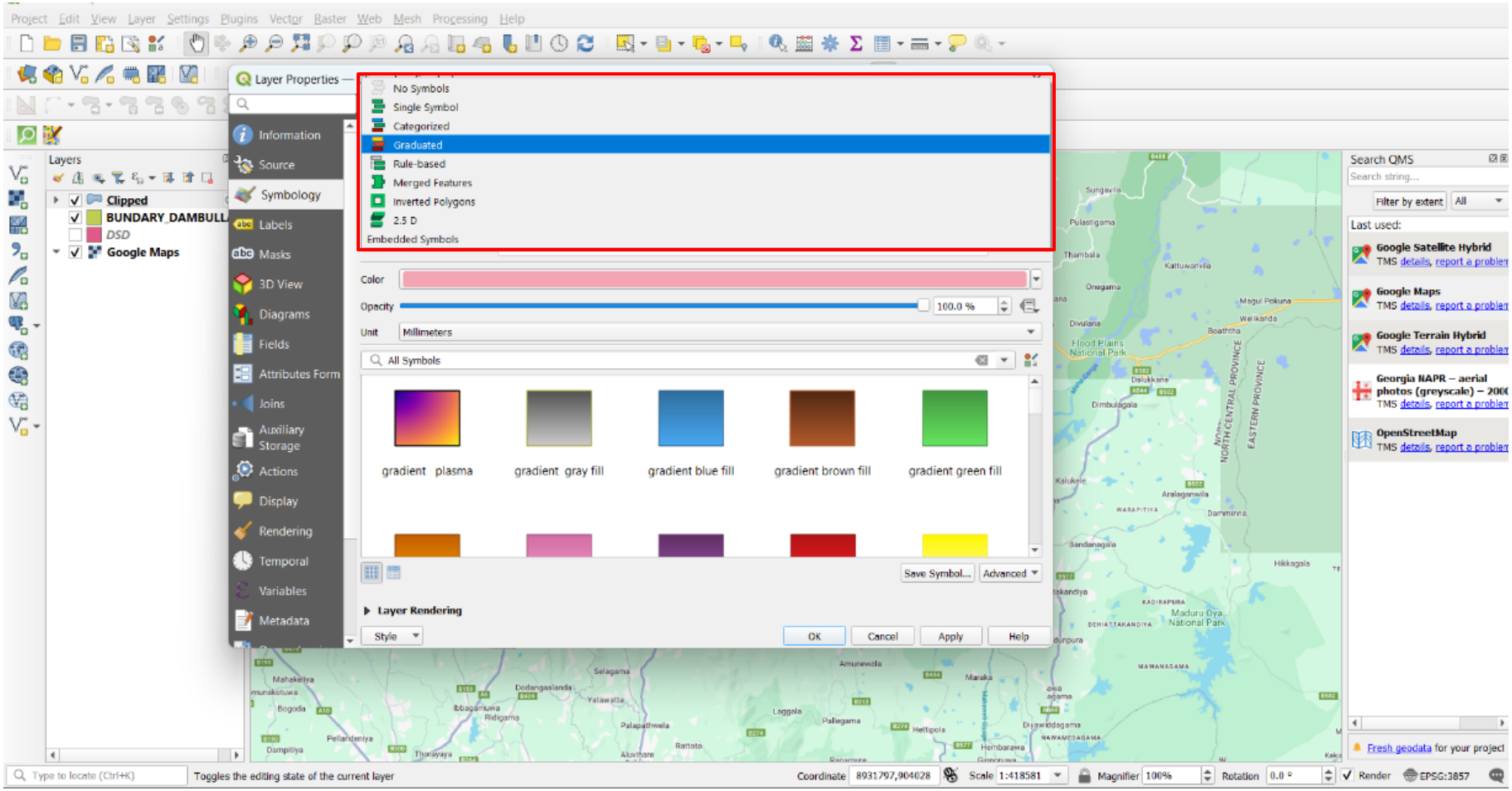
Now the new field will be added to the attribute table. Complete the Population Density column using collected data and save the changes.

	PROVINCE_N	DCODE	DIST	CODE	DIVISEC	POP_Density
1	ntral Province	11	ANURADHAPU...	1115	PALUGASWEWA	NULL
2	North Central Pr...	11	ANURADHAPU...	1116	KEKIRAWA	NULL
3	North Central Pr...	11	ANURADHAPU...	1117	IPALOGAMA	NULL
4	North Central Pr...	11	ANURADHAPU...	1119	PALAGALA	NULL
5	North Central Pr...	12	POLONNARUWA	1203	HINGURAKGODA	NULL
6	North Central Pr...	12	POLONNARUWA	1204	ELAHERA	NULL
7	Central Province	31	MATALE	3101	GALEWELA	NULL
8	Central Province	31	MATALE	3102	DAMBULLA	NULL
9	Central Province	31	MATALE	3103	NAULA	NULL
10	Central Province	31	MATALE	3104	PALLEPOLA	NULL

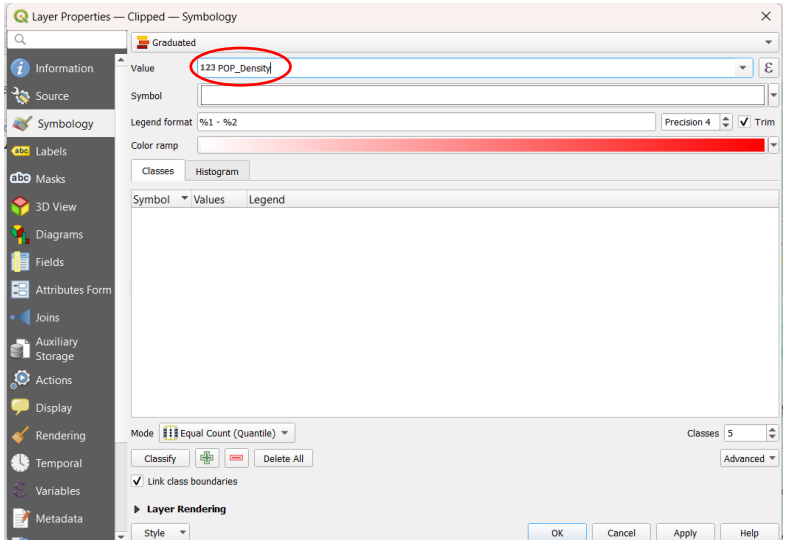
	PROVINCE_N	DCODE	DIST	CODE	DIVISEC	POP_Density
1	NULL ince	11	ANURADHAPU...	1115	PALUGASWEWA	84
2	North Central Province	11	ANURADHAPU...	1116	KEKIRAWA	195
3	North Central Province	11	ANURADHAPU...	1117	IPALOGAMA	288
4	North Central Province	11	ANURADHAPU...	1119	PALAGALA	165
5	North Central Province	12	POLONNARUWA	1203	HINGURAKGODA	100
6	North Central Province	12	POLONNARUWA	1204	ELAHERA	136
7	Central Province	31	MATALE	3101	GALEWELA	404
8	Central Province	31	MATALE	3102	DAMBULLA	176
9	Central Province	31	MATALE	3103	NAULA	106
10	Central Province	31	MATALE	3104	PALLEPOLA	393

06. Categorize according to the population Density.

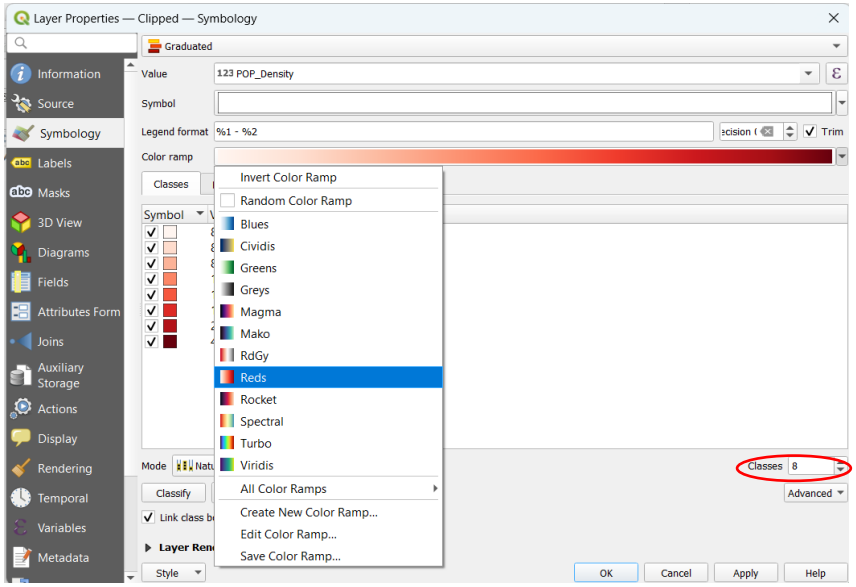
Right-click on the layer > Properties > Symbology > Graduated



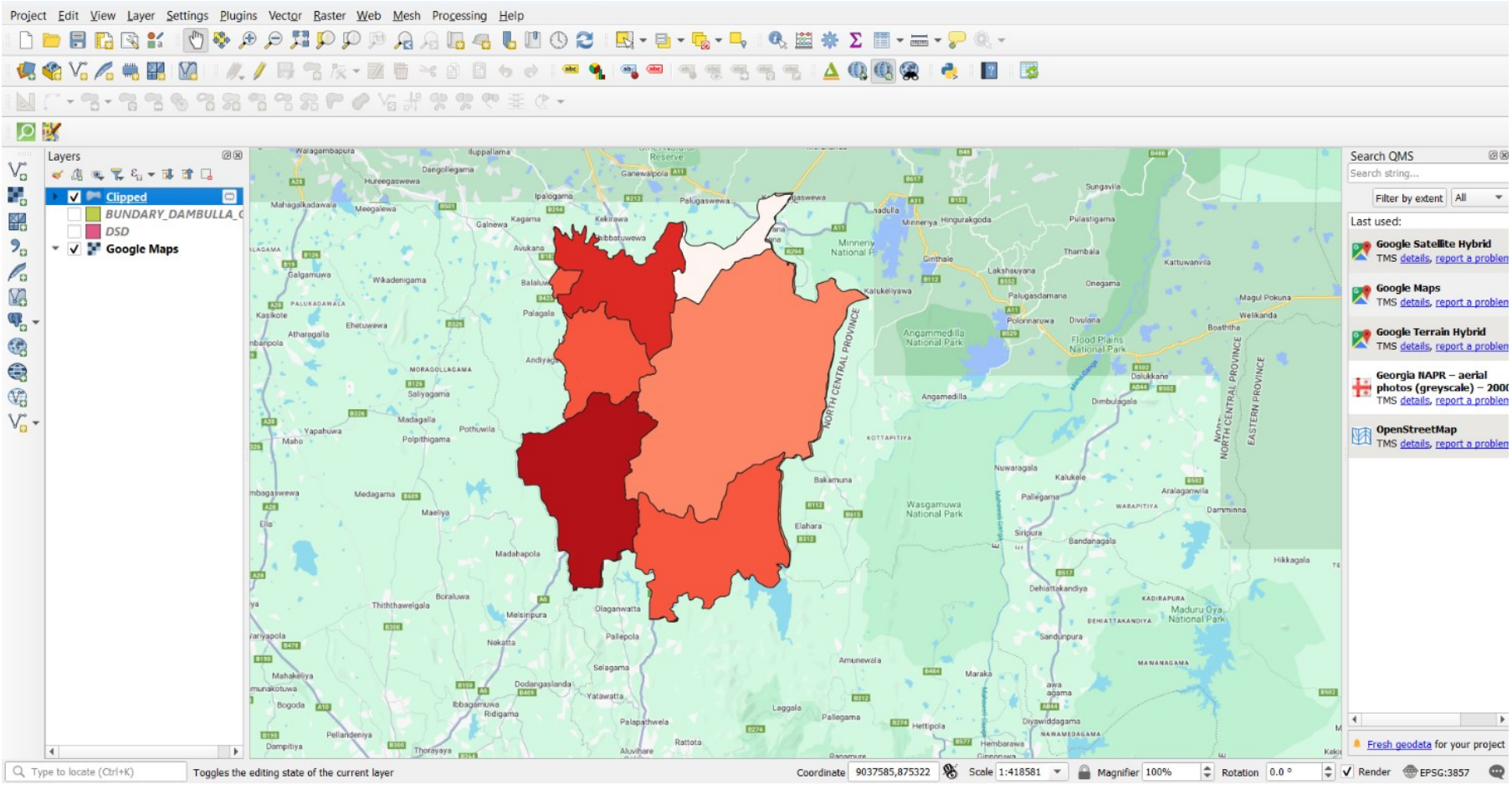
Select **Pop_Density** as the value.



Select the appropriate color ramp and **number of classes > Classify > Apply > OK**



This is the output vector layer for the population density of the Dambulla area.



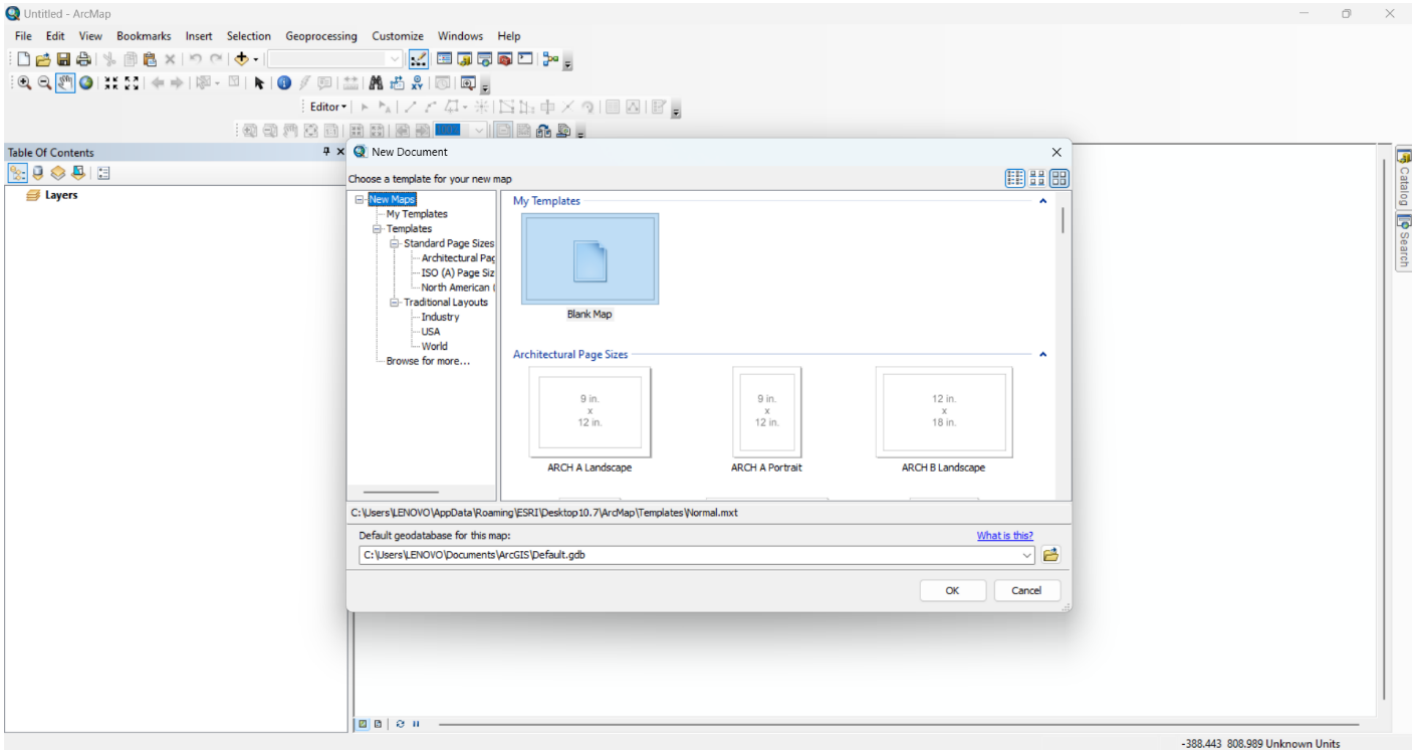
As mentioned in the first part of this document, this vector layer should be converted to a raster layer using QGIS or ArcMap. After that, if the cell size, row, and column values are not the same, the resampling process should be done.

6. Access to services

Conducting an access to services analysis is essential for identifying gaps in service delivery, improving accessibility, and ensuring equity. This analysis helps in efficient resource allocation, strategic planning, and informed policy-making. It also enhances service quality through user feedback, ensures compliance and accountability, and fosters community engagement and empowerment. Also, it provides economic and social benefits, supports benchmarking and best practices, and establishes a framework for ongoing monitoring and evaluation. Overall, it ensures services effectively meet the needs of all community members, promoting social cohesion and stability.

1. Open Arc GIS

New maps > Blank map > OK

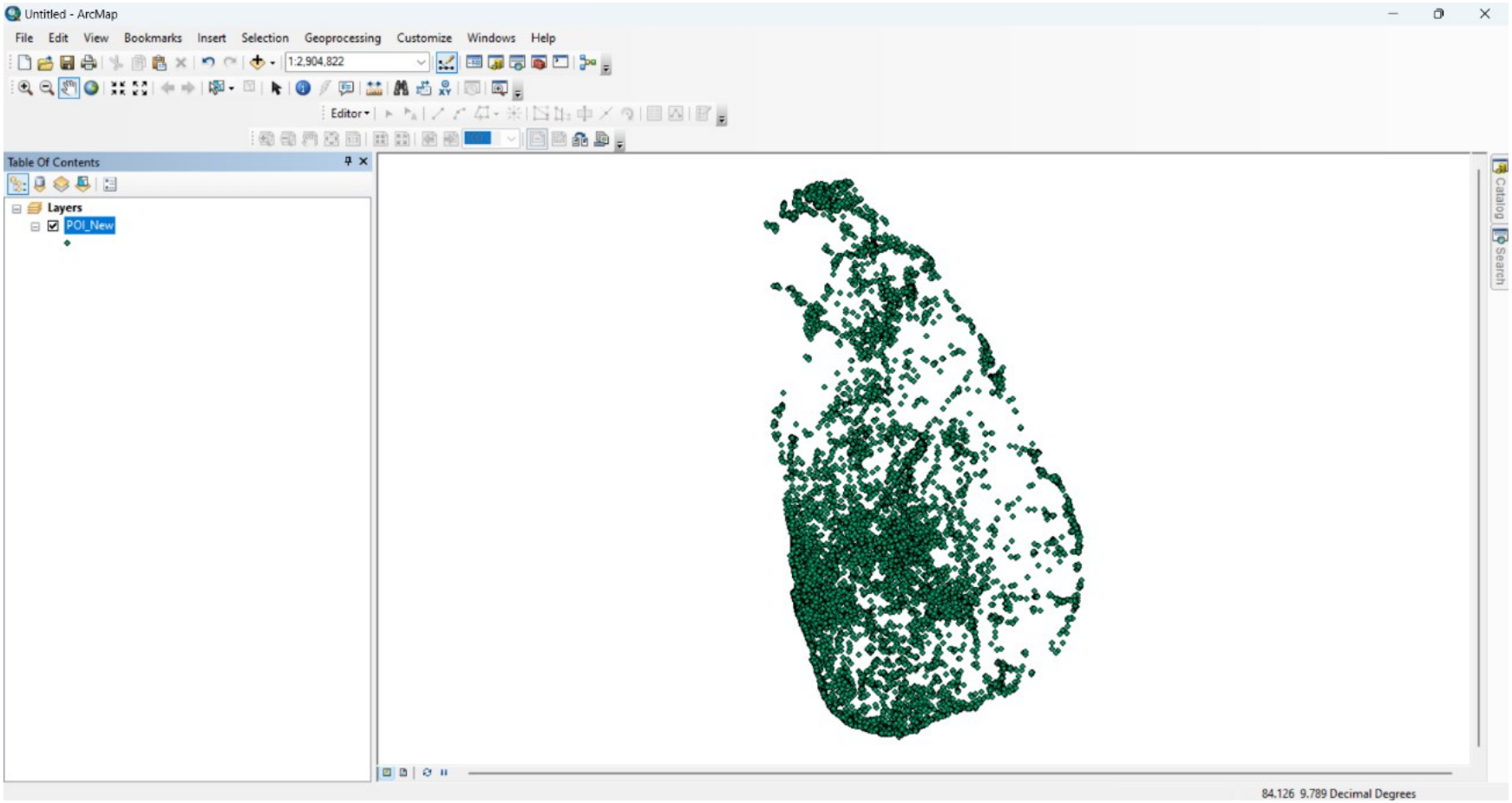


2. Add Shapefiles to the Map

i. Navigate and select POI data.

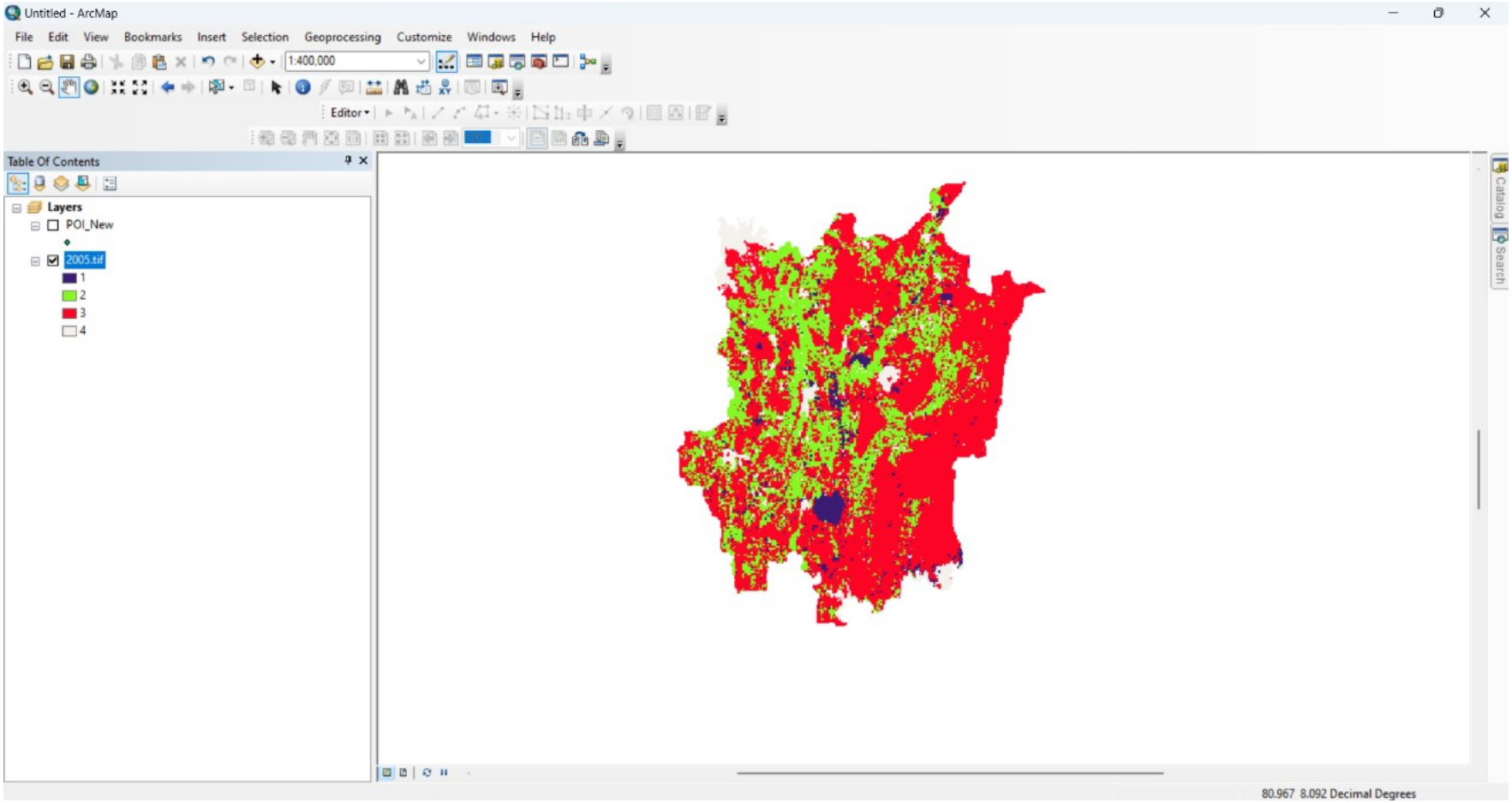
How to download POI data:(Refer 15 min city book)

Go to **File > Add Data > Add Data > Select POI data > Add > OK**



ii. Add land use layer (2005) to the ArcMap. (The 2005 land use raster layer is needed because the raster file that is being created now wants to follow the same pixel size of the land use layer.

Go to **File > Add Data > Add Data > Select Land use layer (2005) > Add > OK**



3. Clip the POI data layer with the Land use layer.

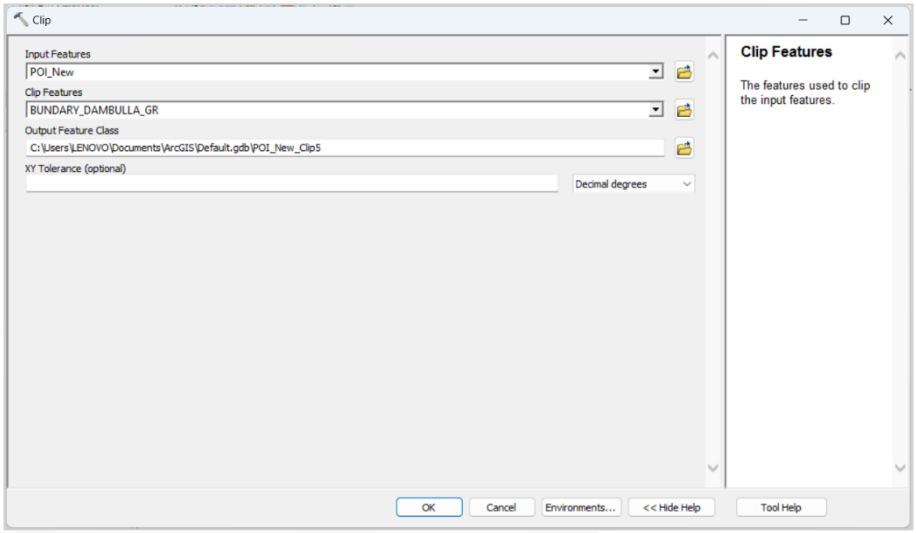
Search for the clip (Analysis) for this step.

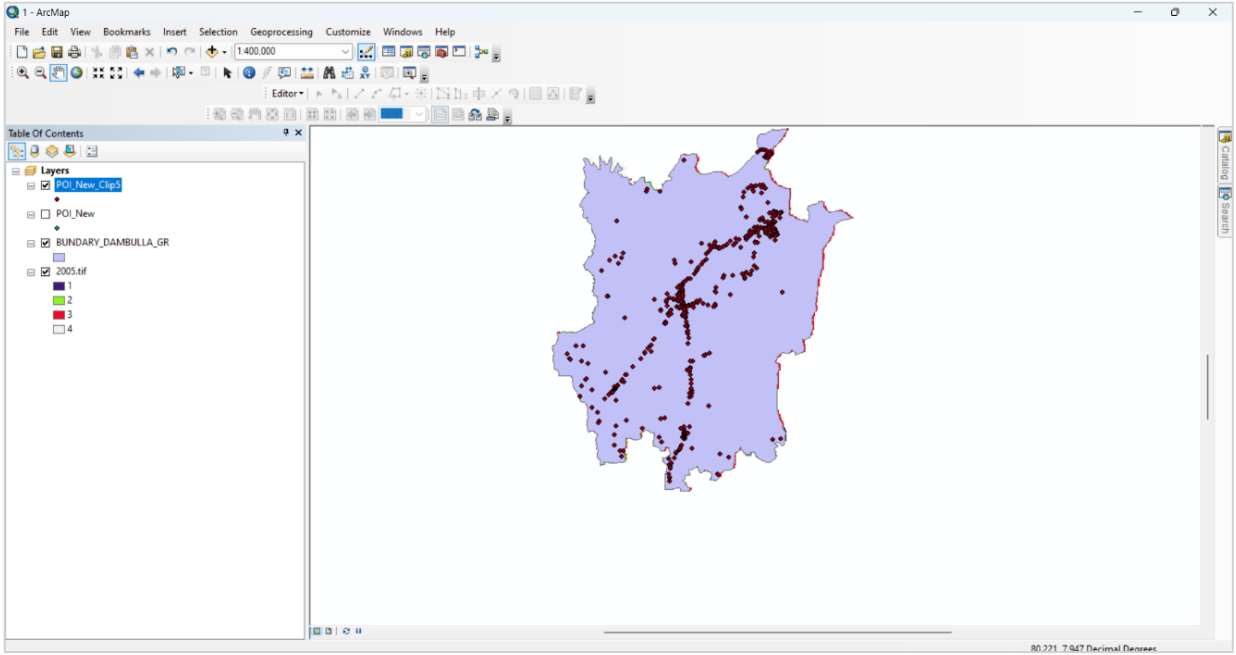
i. **Input features -** POI data layer.

ii. **Clip features -** Layer of the boundary of the study area.

iii. Give a path for the output.

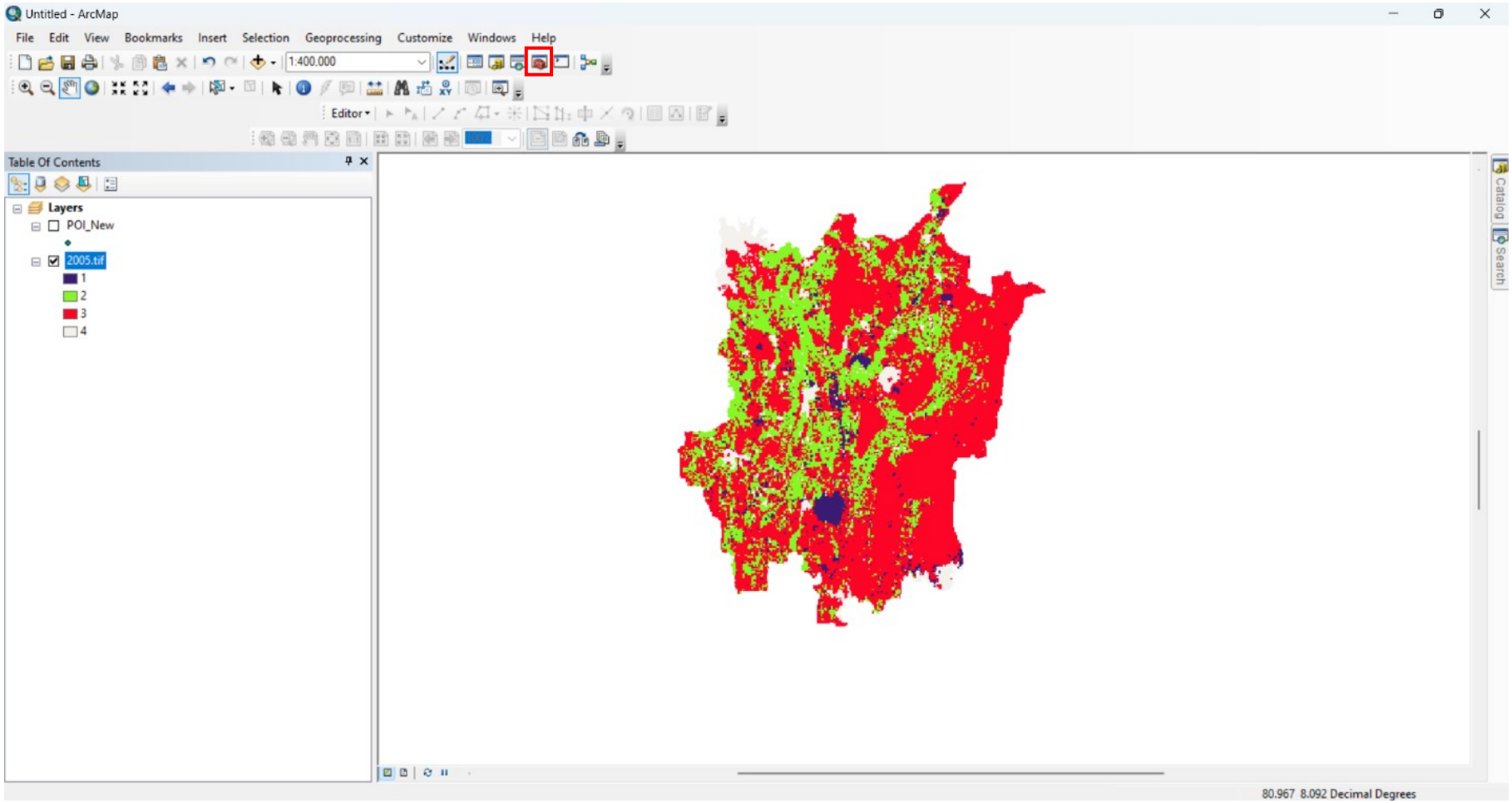
iv. Click "**OK**"



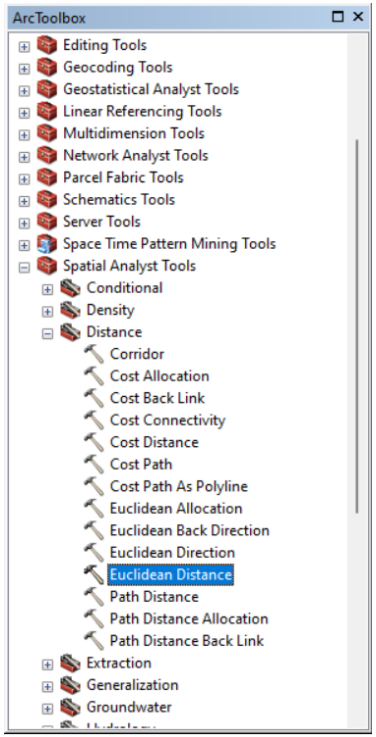


4. Run the Euclidean Distance tool.

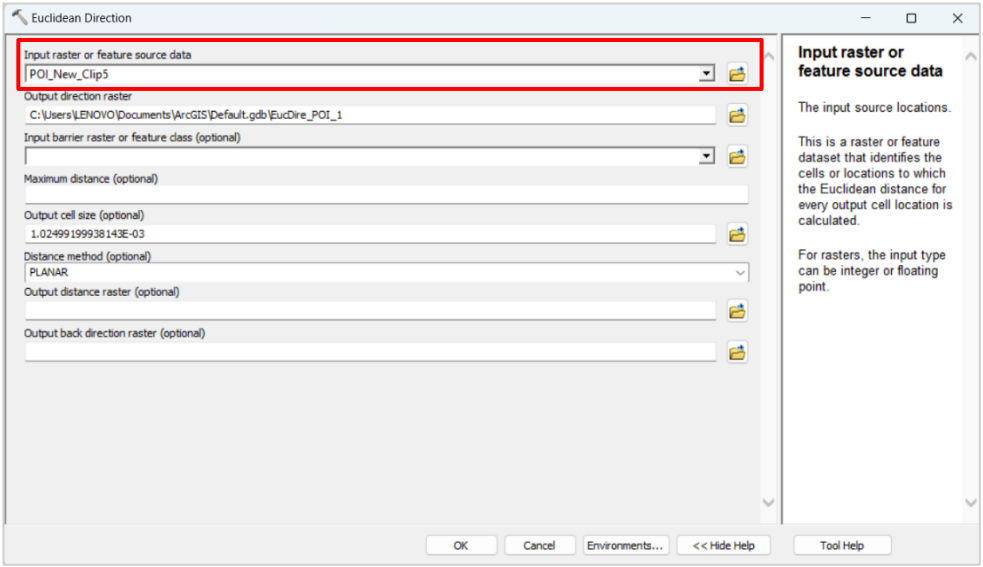
Open ArcToolBox.



Go to **Arc Toolbox > Spatial Analyst Tools > Distance > Euclidean Distance**



i. Input the **Clipped POI data layer** as input raster here.



ii. Go to the environment setting and set the following.

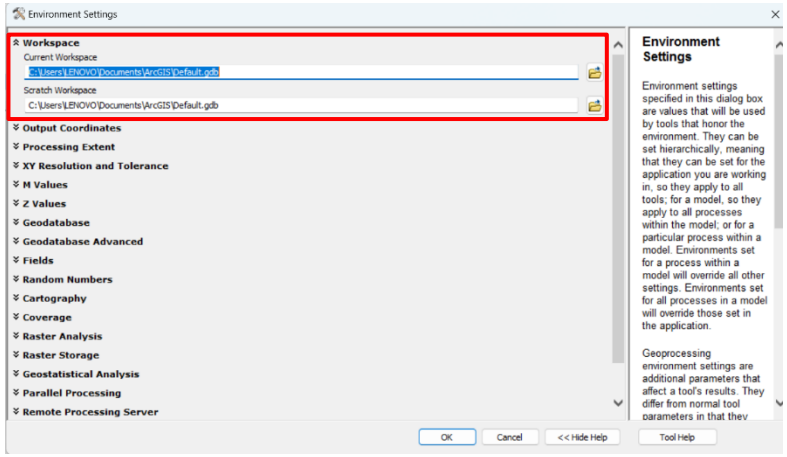
Workspace: Set the current and scratch workspace.

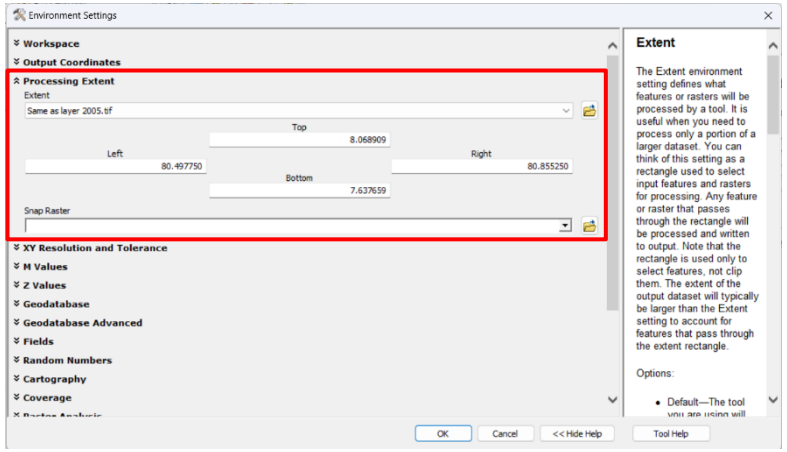
Processing Extent: Set to the same as your land use layer.

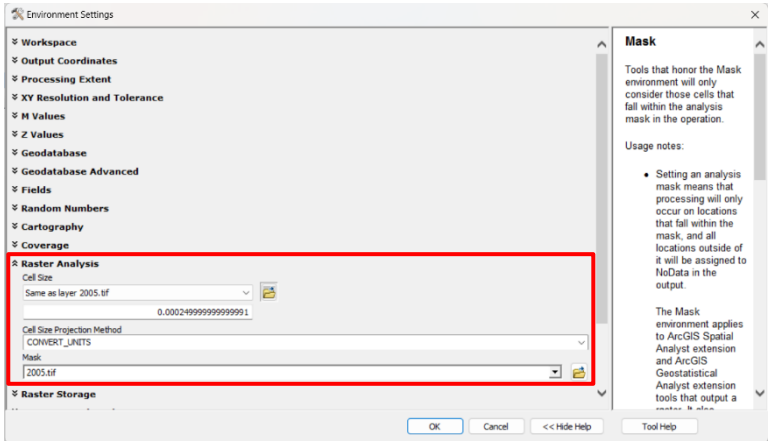
Raster Analysis Settings:

Cell Size: Set the cell size (pixel size) to match the resolution of your land use layer.

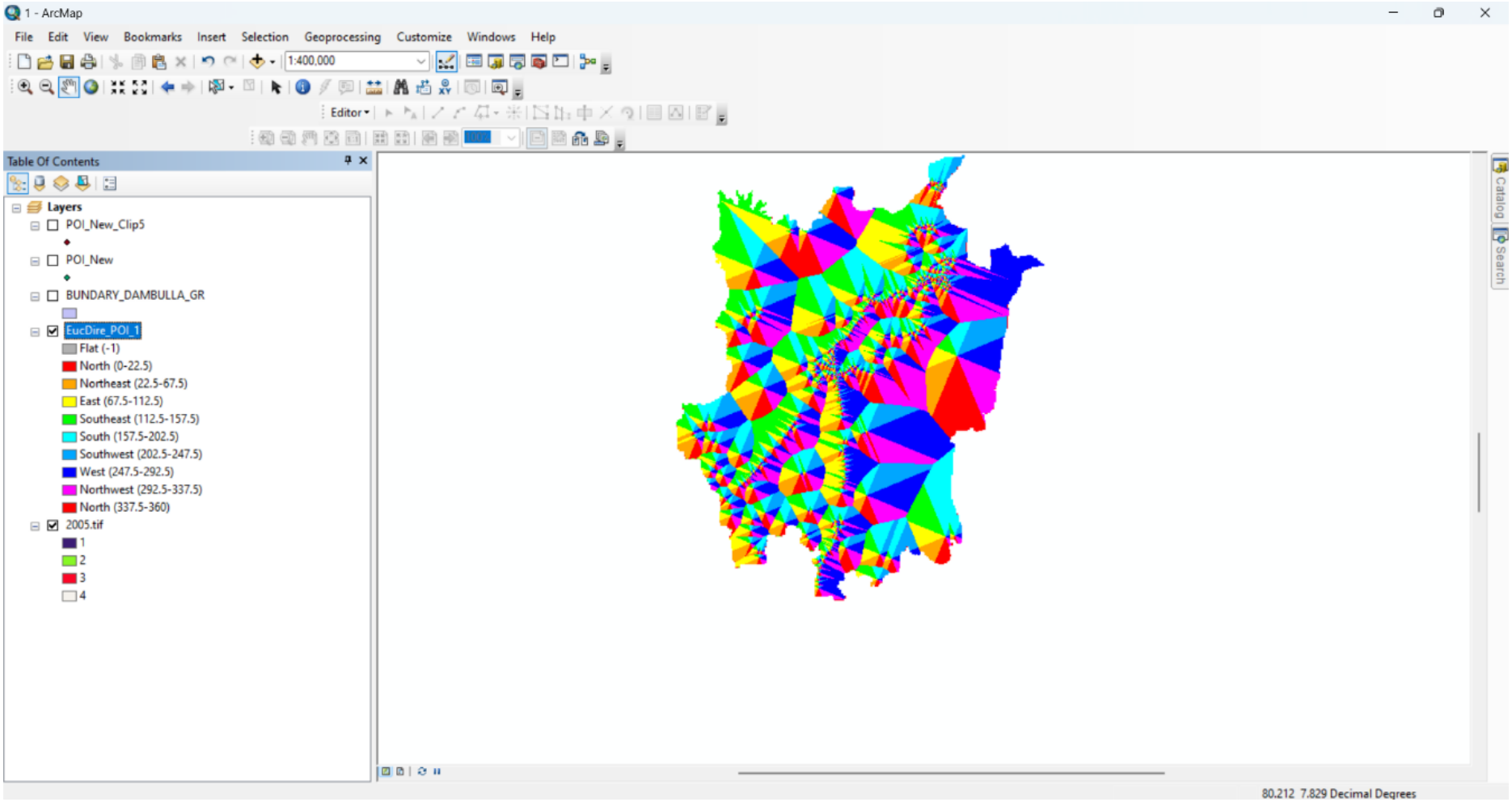
Mask: Set the mask to your land use layer to ensure the output raster matches the area of interest.







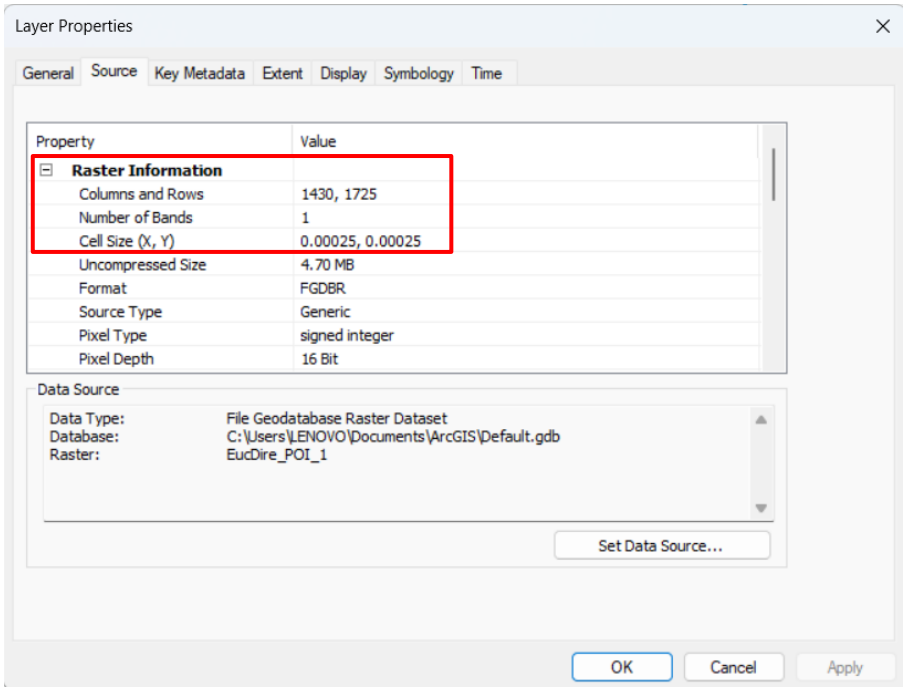
This is the final output.

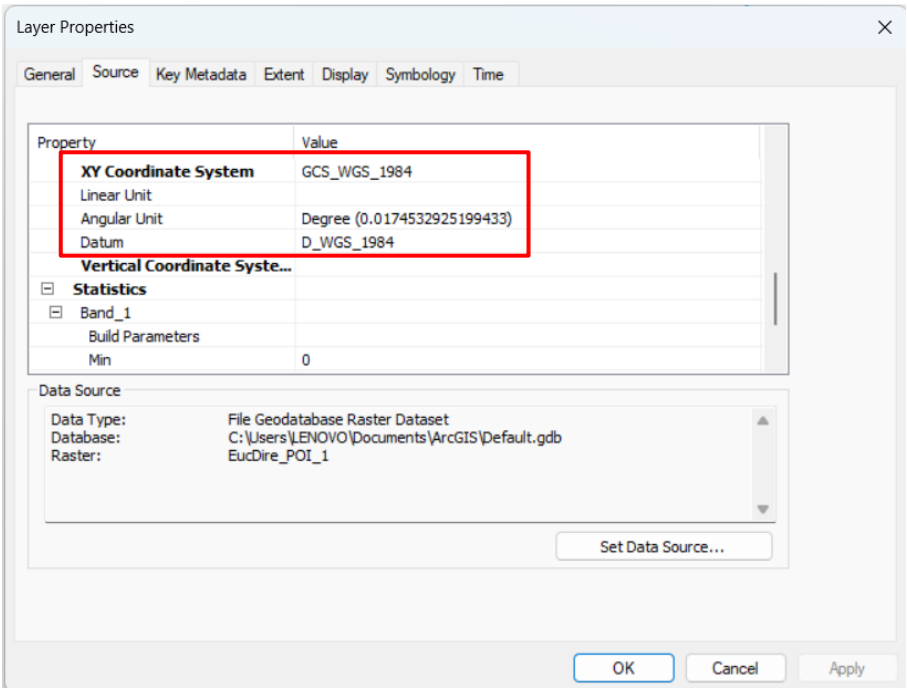


5. **Review the raster layer**

Check whether the Coordinate system and Pixel size are the same for the land use layer by Layer properties.

Right Click on the layer > Properties





- Pixel size, row-column sizes, and coordinate systems are the same as the land use layer. So, no need to make any changes.
- By following these steps, you can make the "**Access to service**" raster layer.

7. Accessibility

Accessibility is a crucial spatial variable often used in land use change modeling, including in the MOLUSCE plugin. It refers to the ease with which different locations can be reached from a particular point, influencing land use patterns and development. High accessibility areas, such as those near roads, urban centers, or transportation hubs, are more likely to experience development and land use changes due to better connectivity and the movement of people and goods.

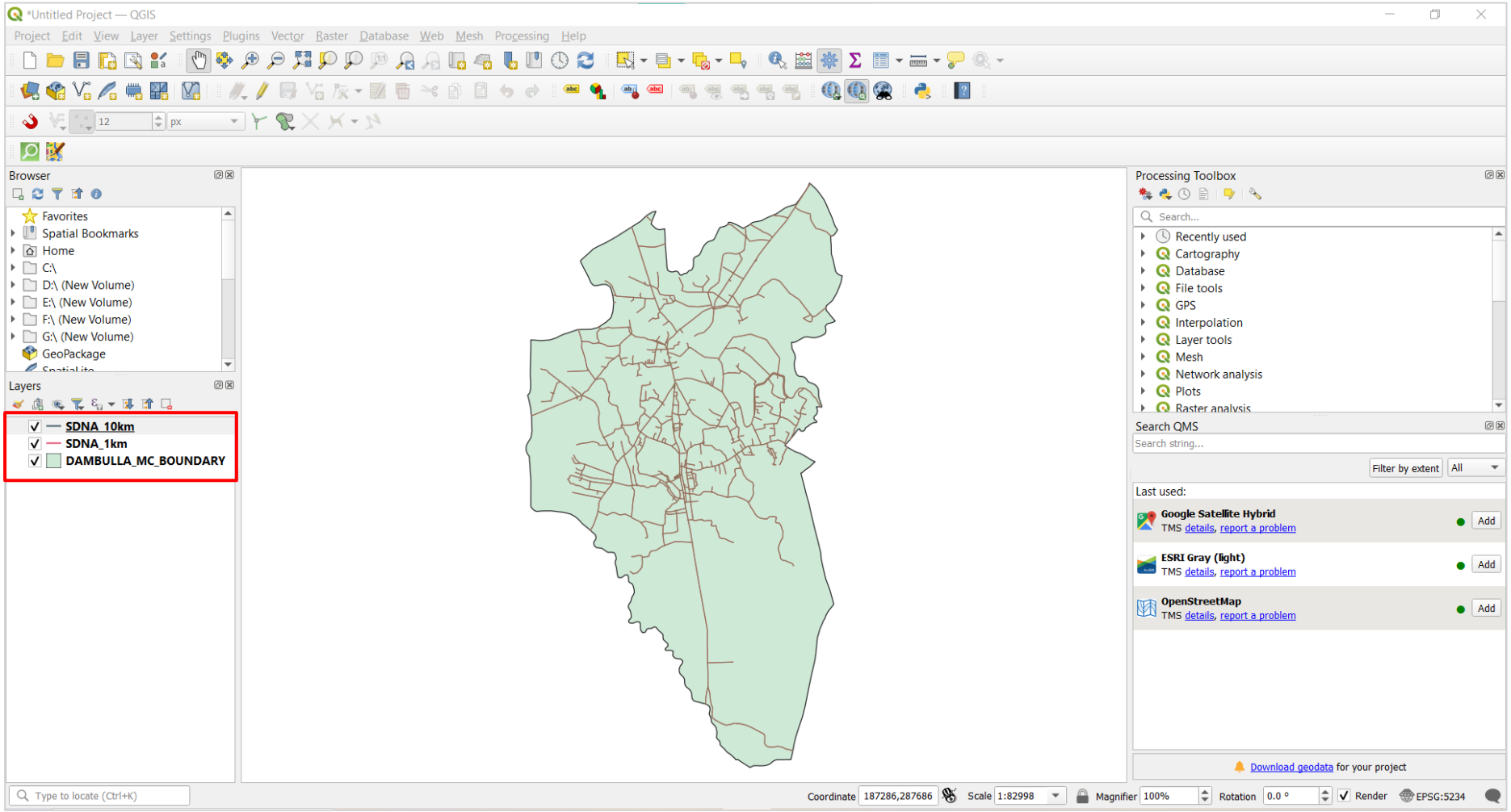
In the context of land use modeling, accessibility can be quantified by measuring distances to key infrastructure elements like roads, highways, city centers, or public transportation stations. This variable helps predict how proximity to these elements affects land-use transitions, such as urban expansion or agricultural development. By incorporating accessibility as a spatial variable, models like MOLUSCE can more accurately simulate and forecast future land use changes, aiding in effective planning and resource management. Here are the basic steps for how to create a raster layer for accessibility using the **Dambulla MC boundary**. Although we explain how to create this layer using a different area extent here, all spatial variables and land use layers should have the same area extent.

First, we have to prepare a sDNA layer using the current road network of the selected area. sDNA (Spatial Design Network Analysis) is a powerful tool used to analyze accessibility and connectivity within spatial networks, such as road systems. Also, it is a toolkit that integrates with GIS software to perform network analysis. It evaluates various metrics such as reach, betweenness, closeness, and straightness, which measure how easily different parts of a network can be accessed from any given point. These metrics help in understanding the flow of movement through a network, identifying key corridors, and predicting areas of potential development. This provides valuable insights into how the structure and connectivity of a road network influence land use patterns.

To prepare an sDNA layer for accessibility analysis using a current road layer, start by obtaining a clean, topologically correct vector road network layer, typically in shapefile format. Ensure the sDNA toolkit is installed and configured in your GIS software (e.g., QGIS or ArcGIS). Then, preprocess the road layer to remove any gaps, overlaps, or disconnected segments, and simplify the network if necessary to streamline the analysis.

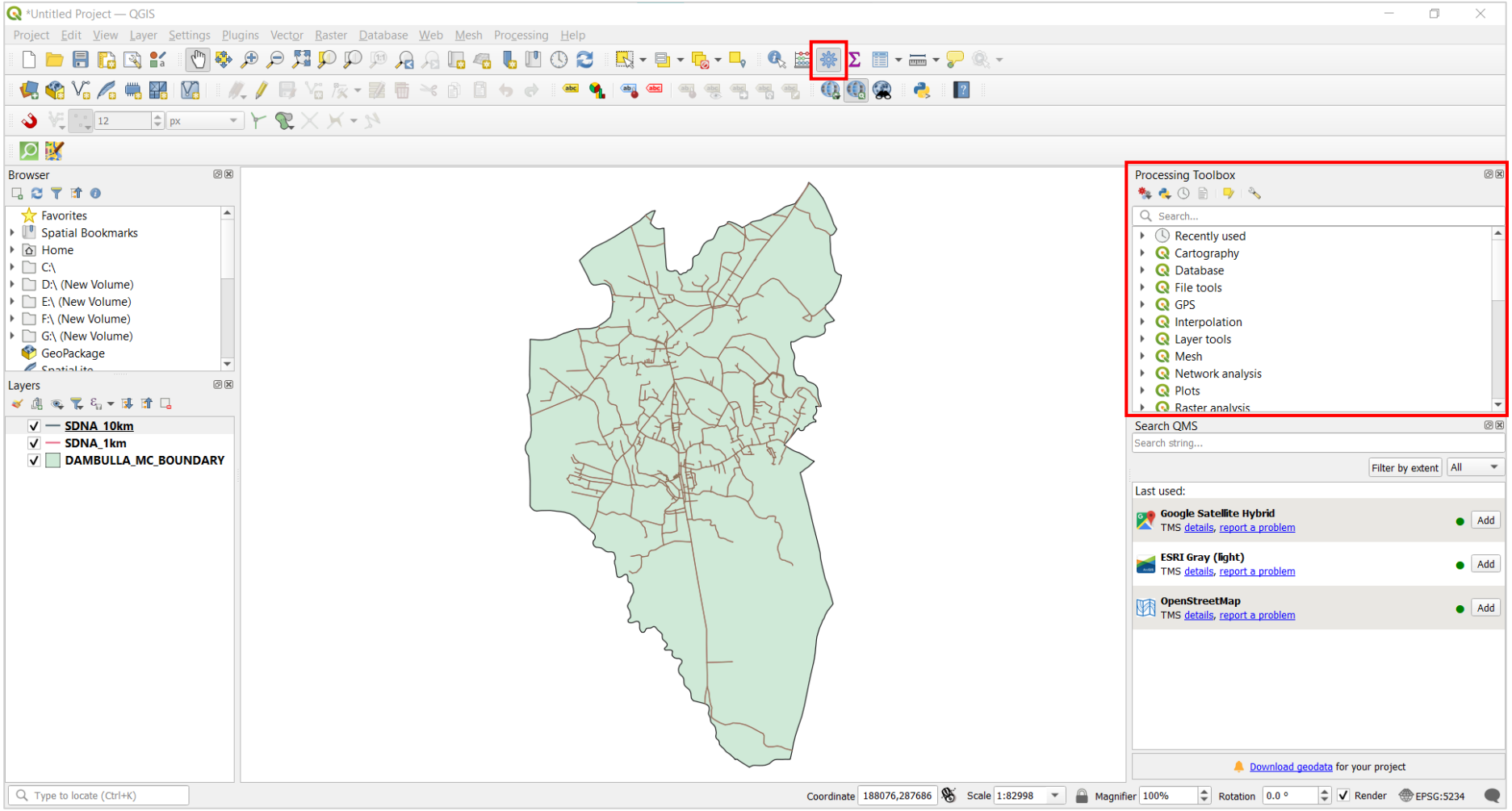
Next, define the parameters for the sDNA analysis, such as the radius of analysis and specific metrics like betweenness and closeness. Run the sDNA tool on the road layer to calculate these accessibility metrics. The output will be a new layer containing these metrics for each road segment, which can be used as input in the MOLUSCE plugin to model the influence of accessibility on land use changes. We have to ensure this sDNA layer aligns correctly with other spatial data layers to validate the results.

Next, open the QGIS and input the boundary, and sDNA data to the interface.



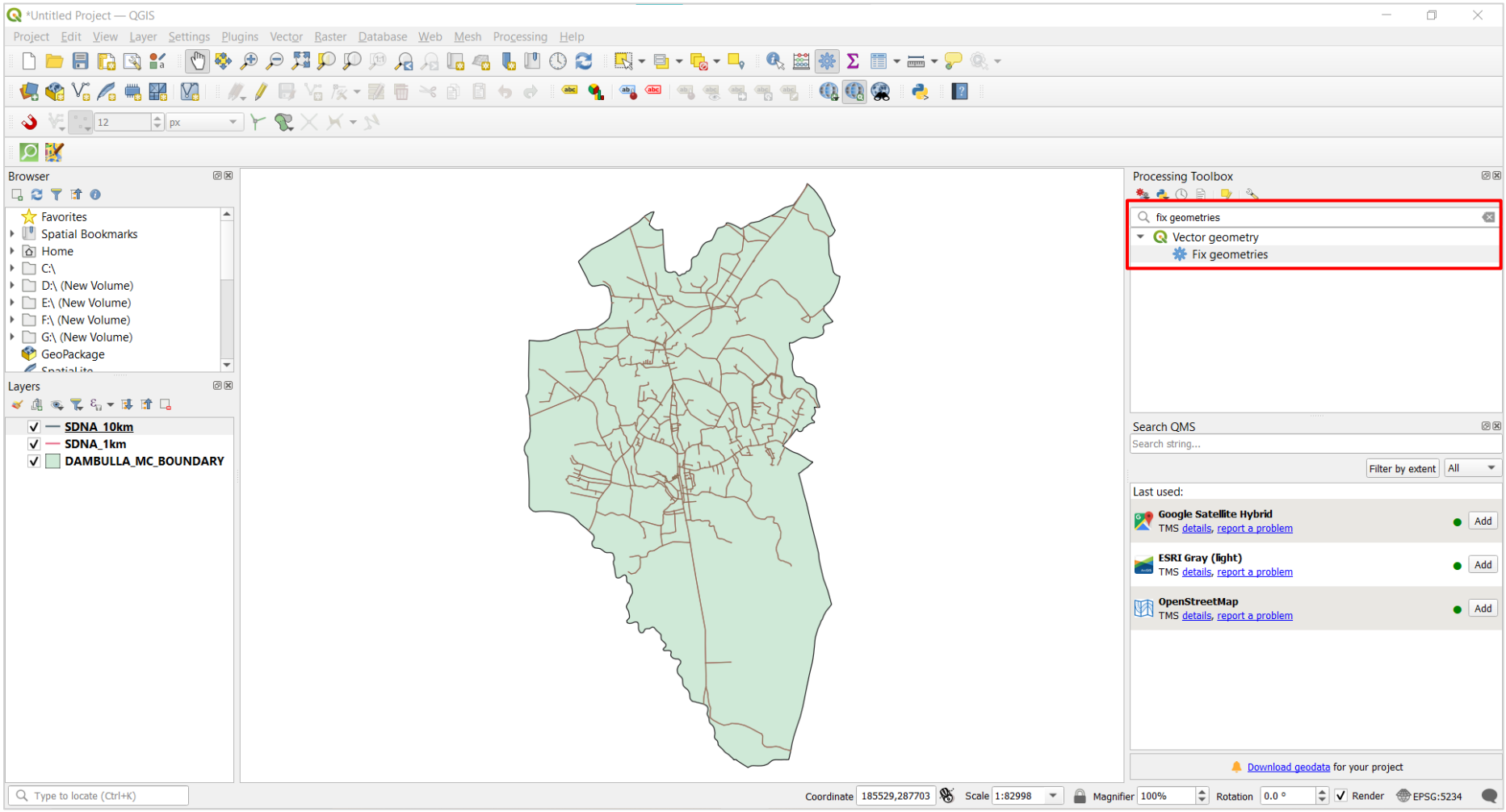
Converting the line feature into points

- First, we have to fix the geometries. For that, click on the processing toolbox and it will open the processing toolbox menu.
-



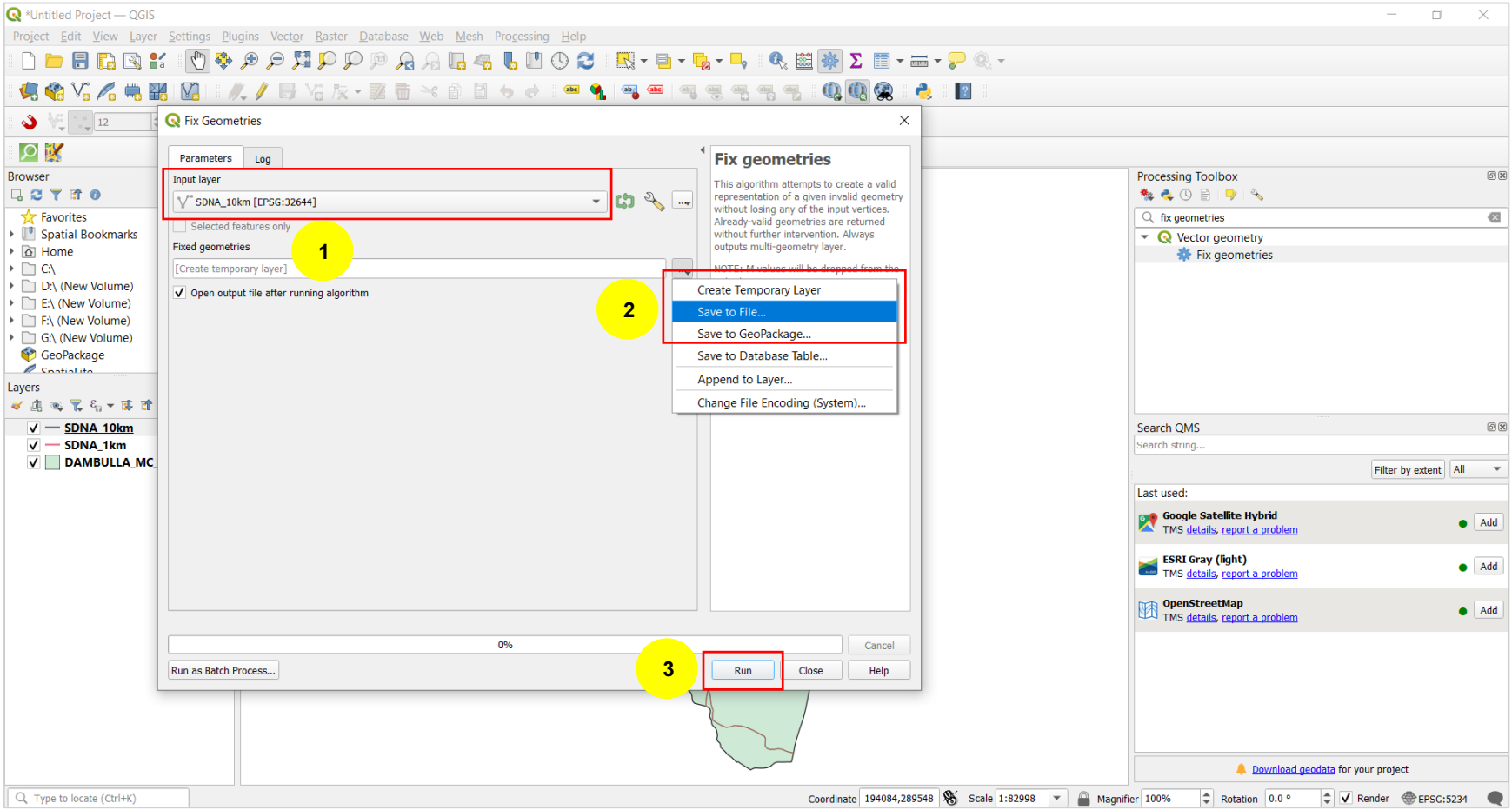
- Now type the “fix geometries” in its search bar.

- So, the fix geometries tool will appear under the menu, and double-click on it.
- Then the fix geometries window will appear and select one of the SDNA layers from the drop-down menu of the input layer. (In this book we have used the



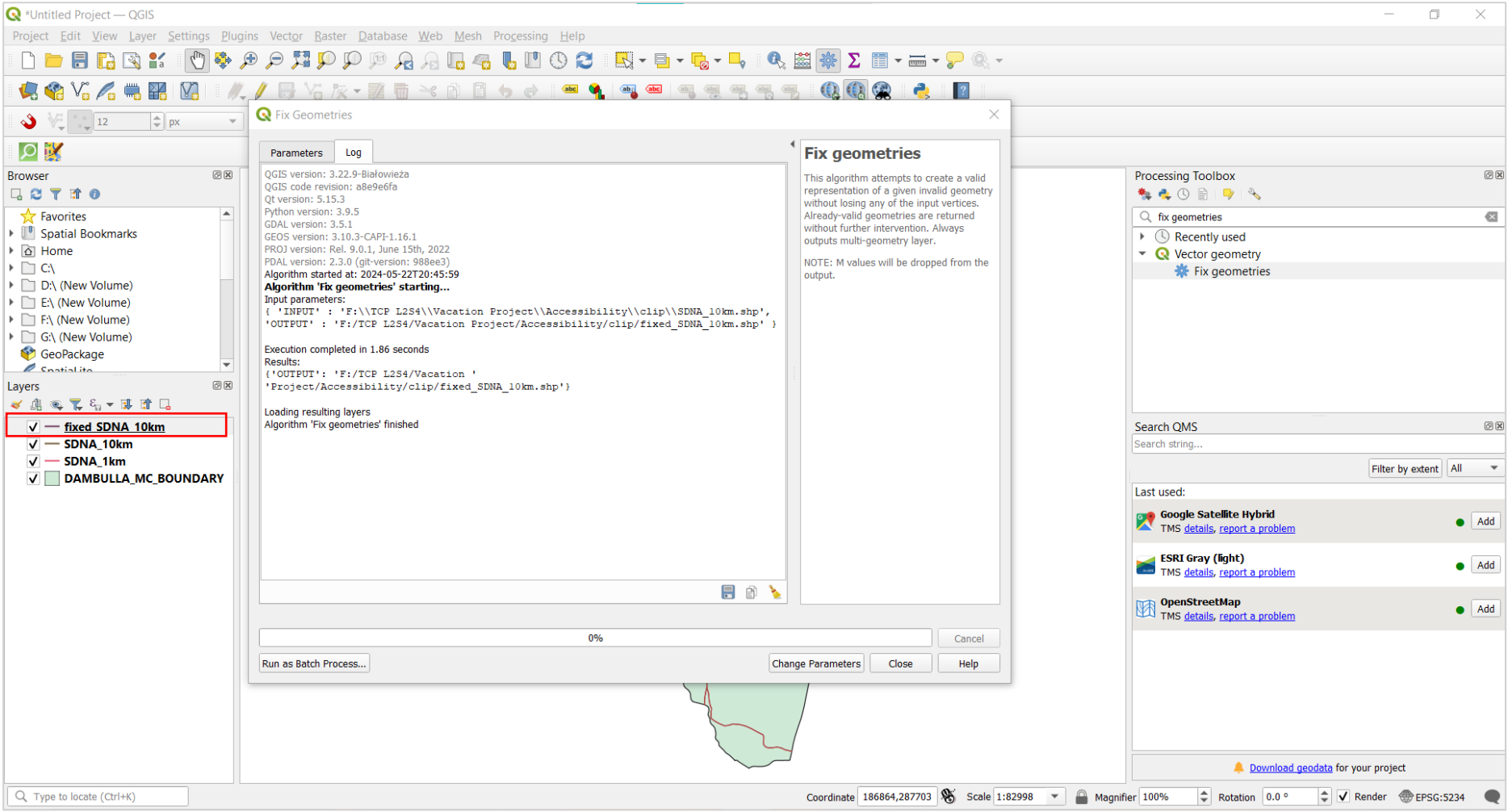
sDNA_10km layer first)

- Click save to file and save your fixed sDNA layer into a folder.Then click on run.

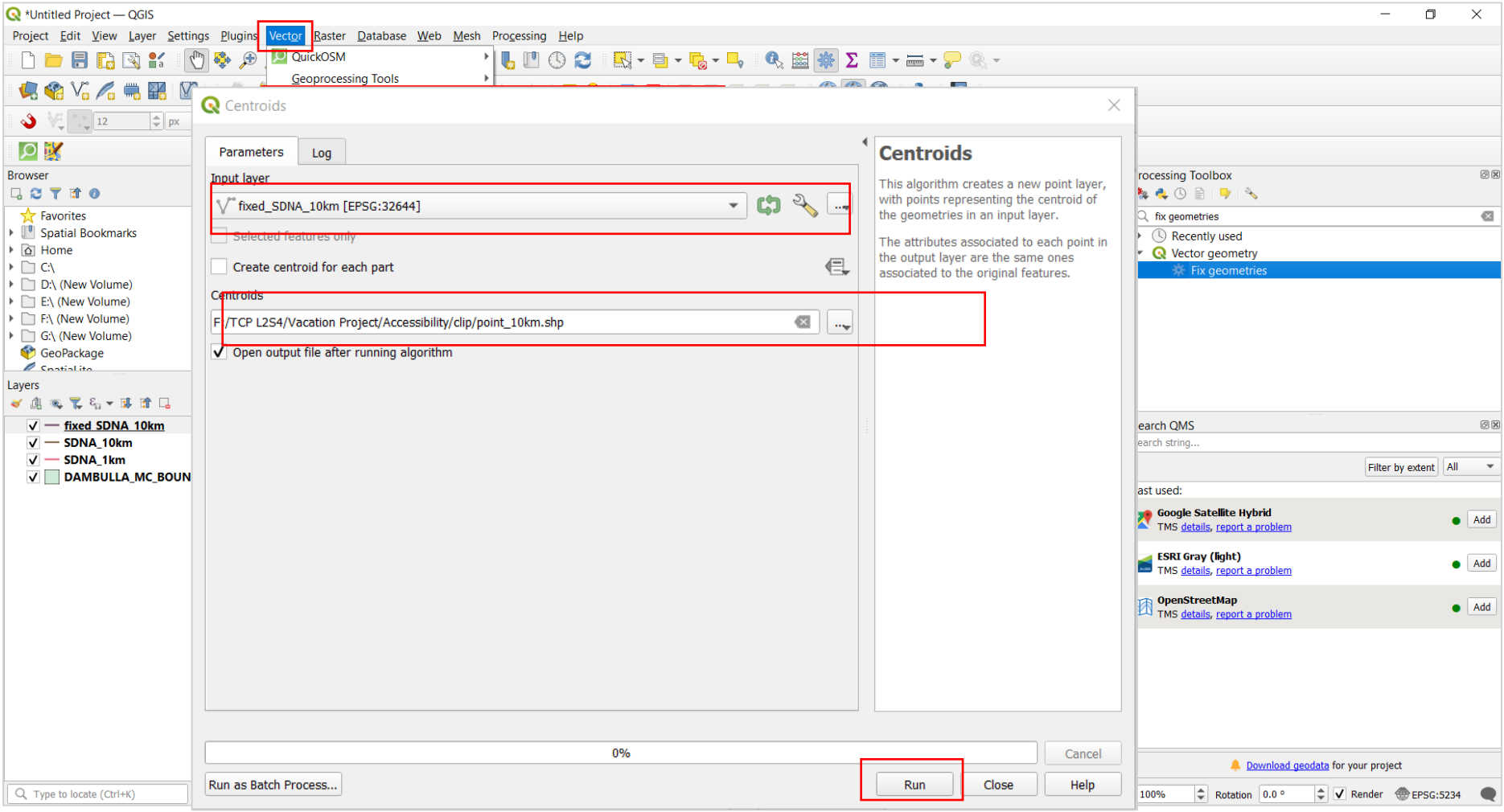


-

- After running the process, you can get your fixed sDNA layer like below.

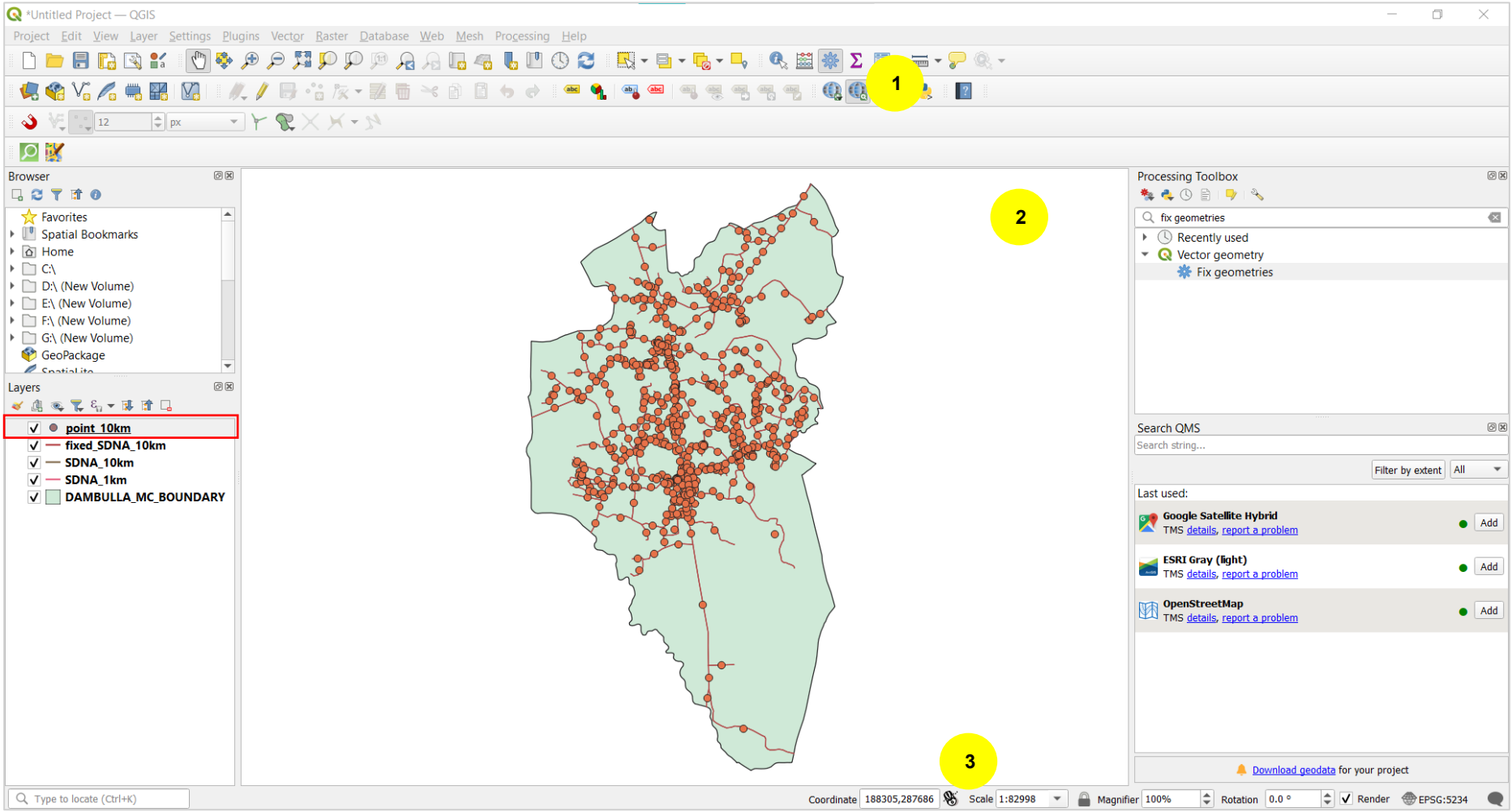


- Next, click on the vector tab.
- Select geometry tools and click on centroids in there.

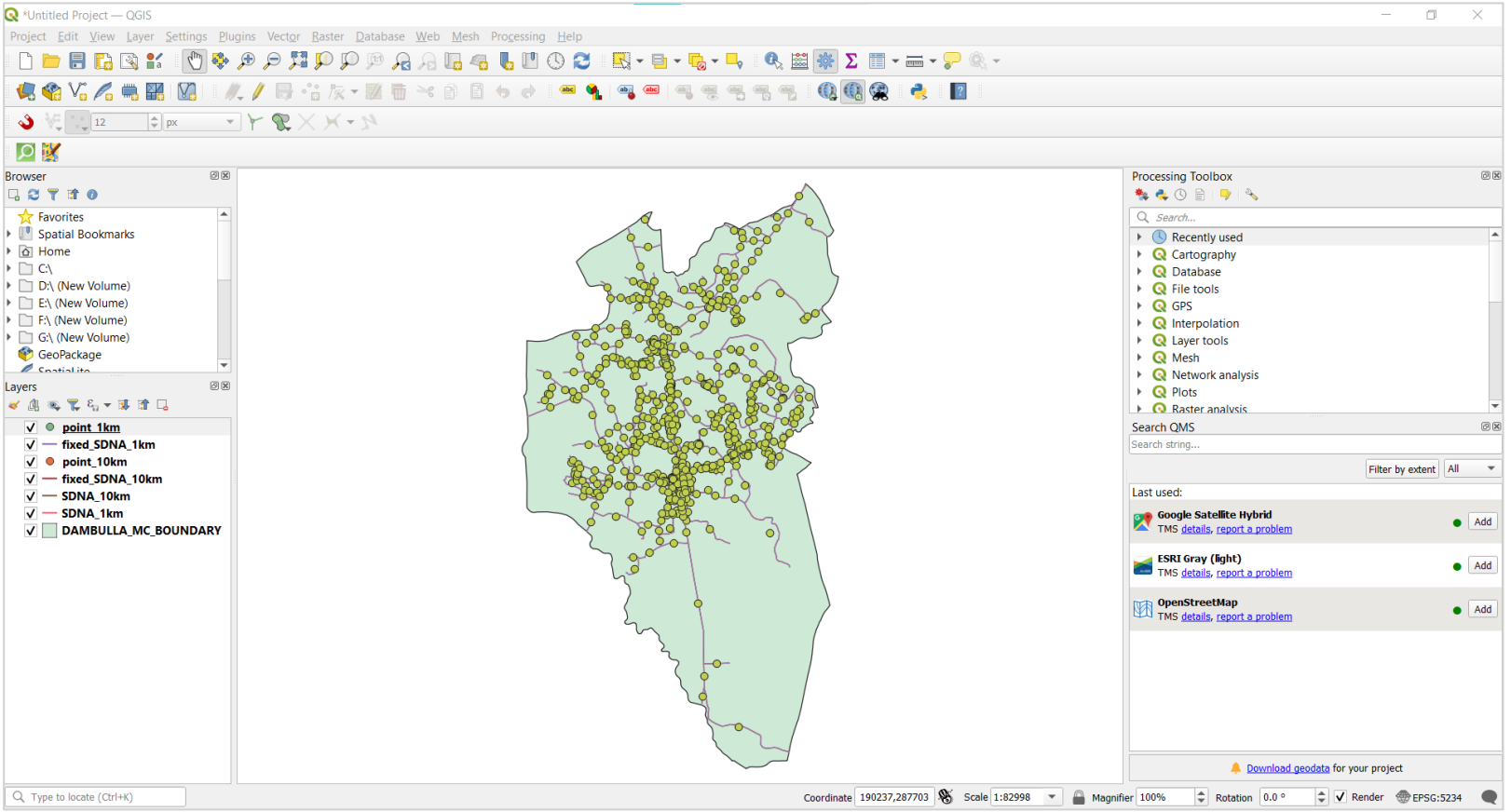


- It will open the centroids window and select the fixed sDNA_10km layer from the drop-down menu in the input layer.

- Save the file in a relevant folder and click on run. (In there we saved the new centroid layer as point_10km)
- After running the process, you can get the point layer for the sDNA dataset.

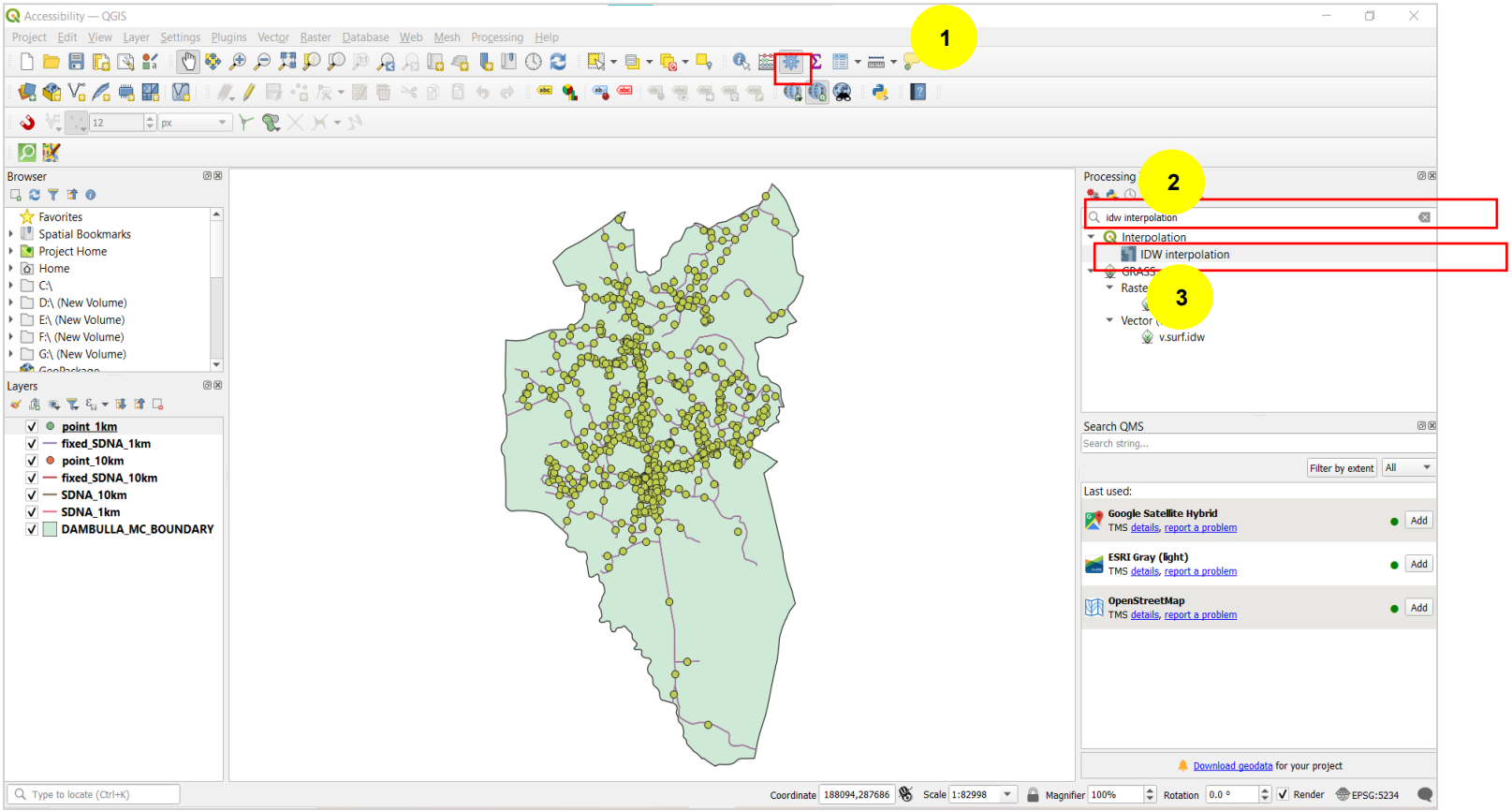


- Following the same process in the above steps, you can fix geometries and then convert the line feature into points in the sDNA_1km layer.
- So, after that, you can get the point layer for both sDNA_10km and sDNA_1km layers. Those point layers are used for the interpolation and creation of raster layers.

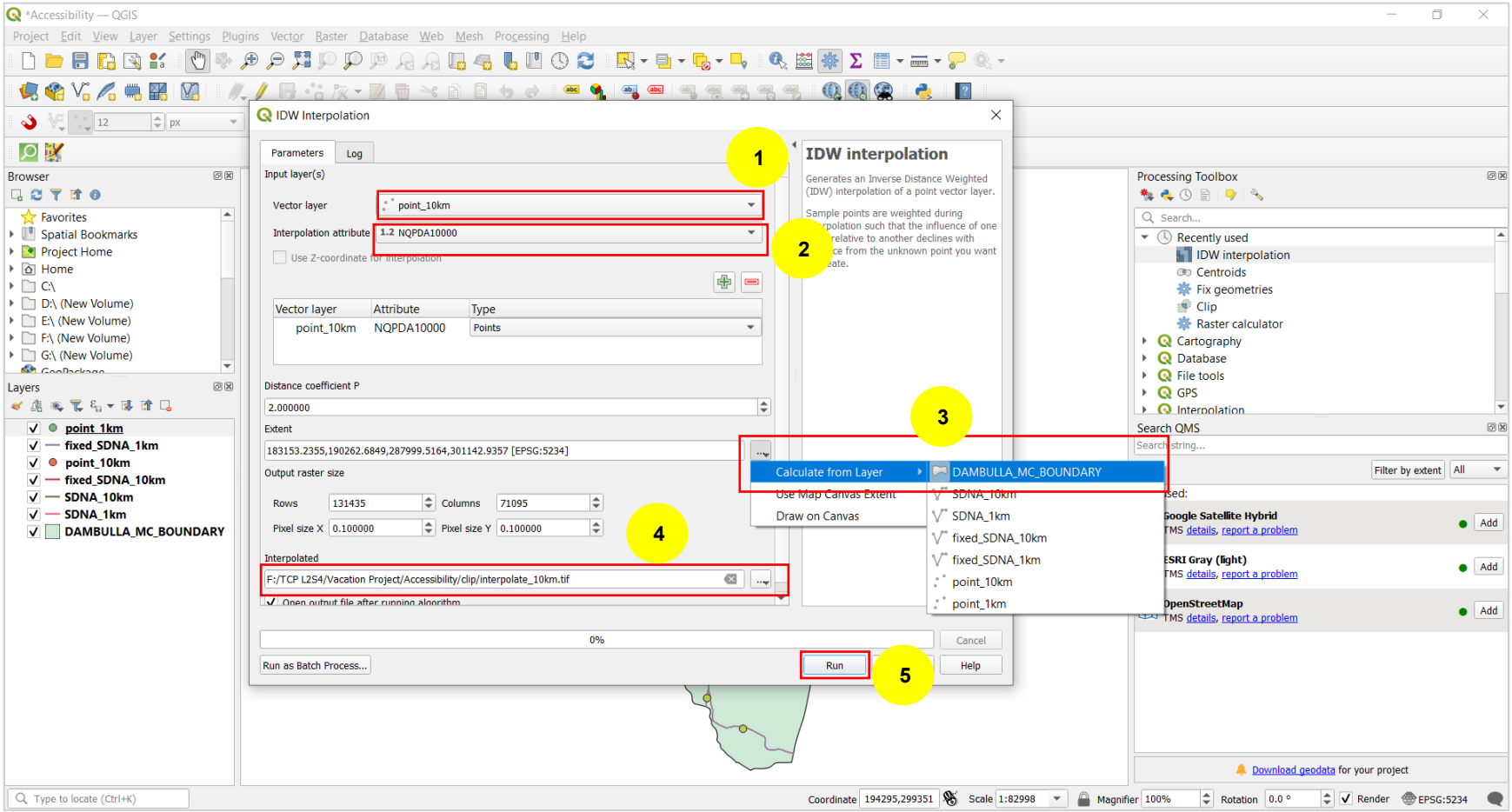


Running the IDW interpolation tool

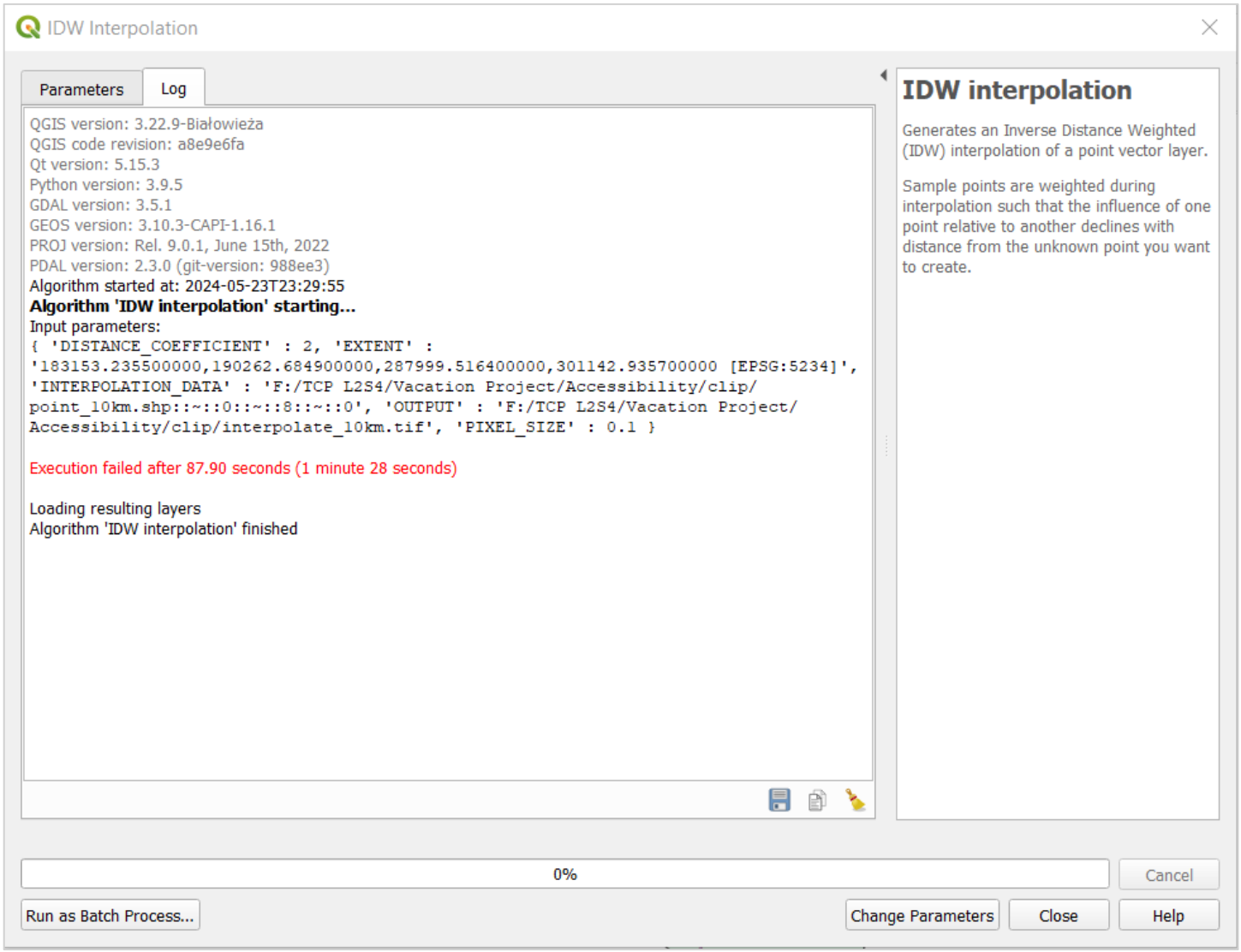
- Click the processing toolbox in the ribbon
- Type IDW interpolation in the search bar of the processing toolbox menu
- The relevant tool will appear under the menu and double-click the IDW interpolation.
- In the IDW interpolation window, select the relevant point layer as the vector layer. (In this book it is point_10km)



- Select the interpolation attribute as **NQPDA10000** in the drop-down menu and click the plus mark below.
- In the extent, select calculate from layer and then click on your relevant boundary. In this book, the extent is the Dambulla MC boundary.
- Then save the interpolated layer to a file on your desktop and click on run to process.



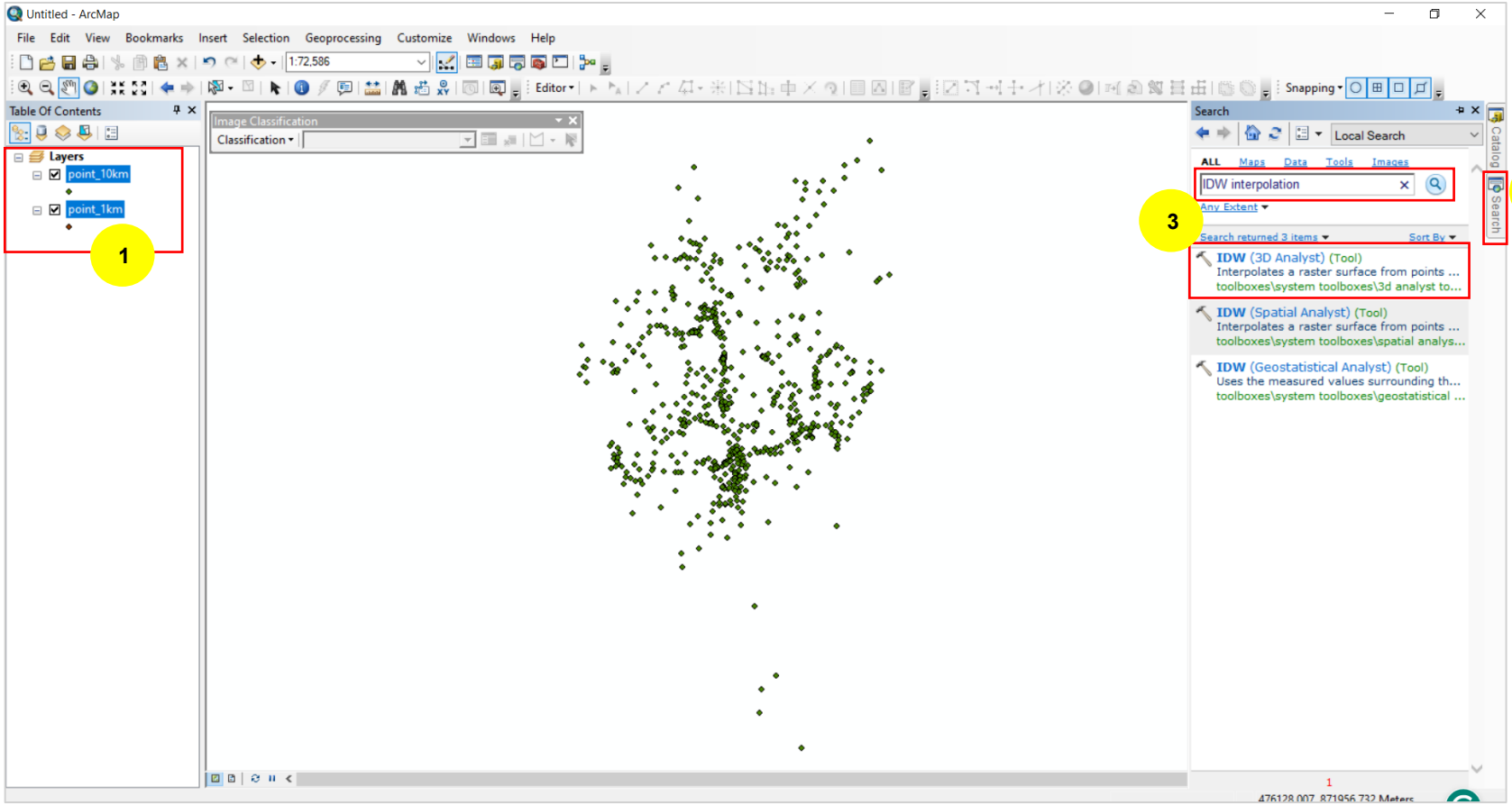
But most probably, we encountered an error in the process of interpolation with the QGIS as follows.



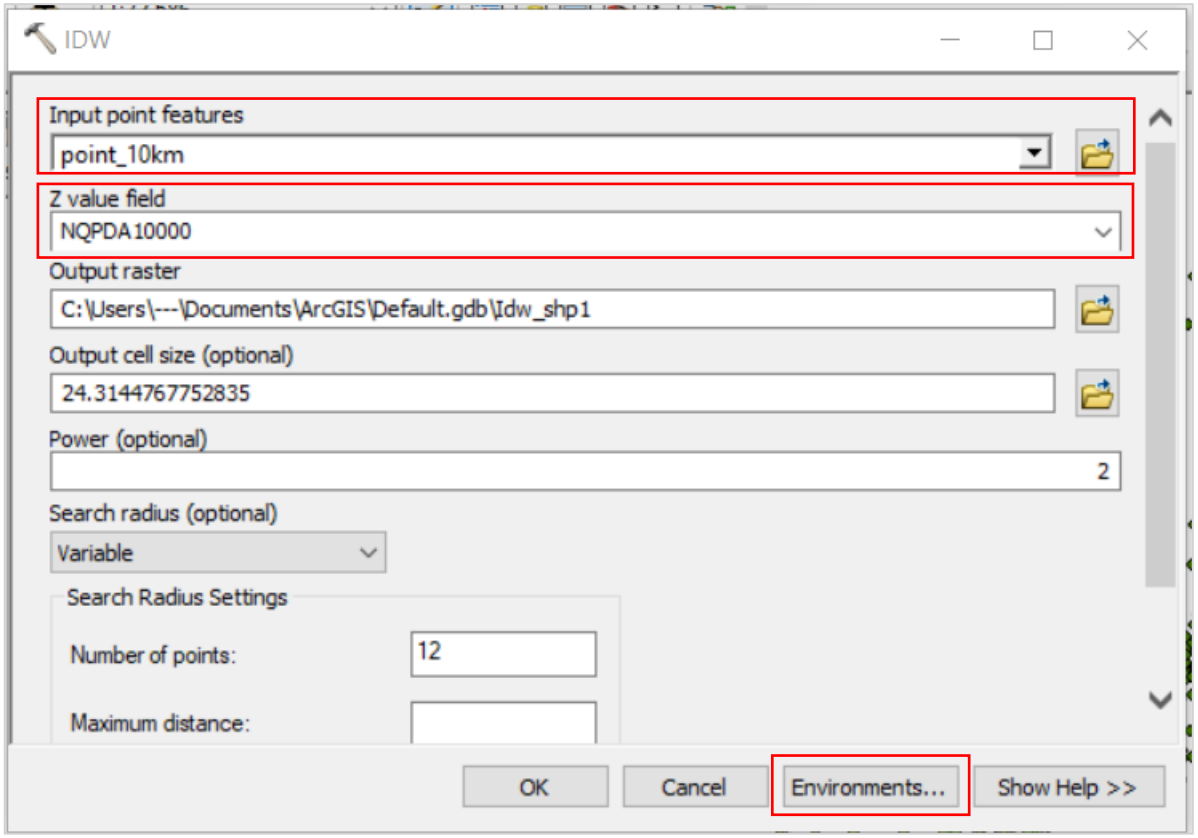
Optional Steps

Because of the error encountered in the QGIS, we have done the interpolation process using Arc Map. For that,

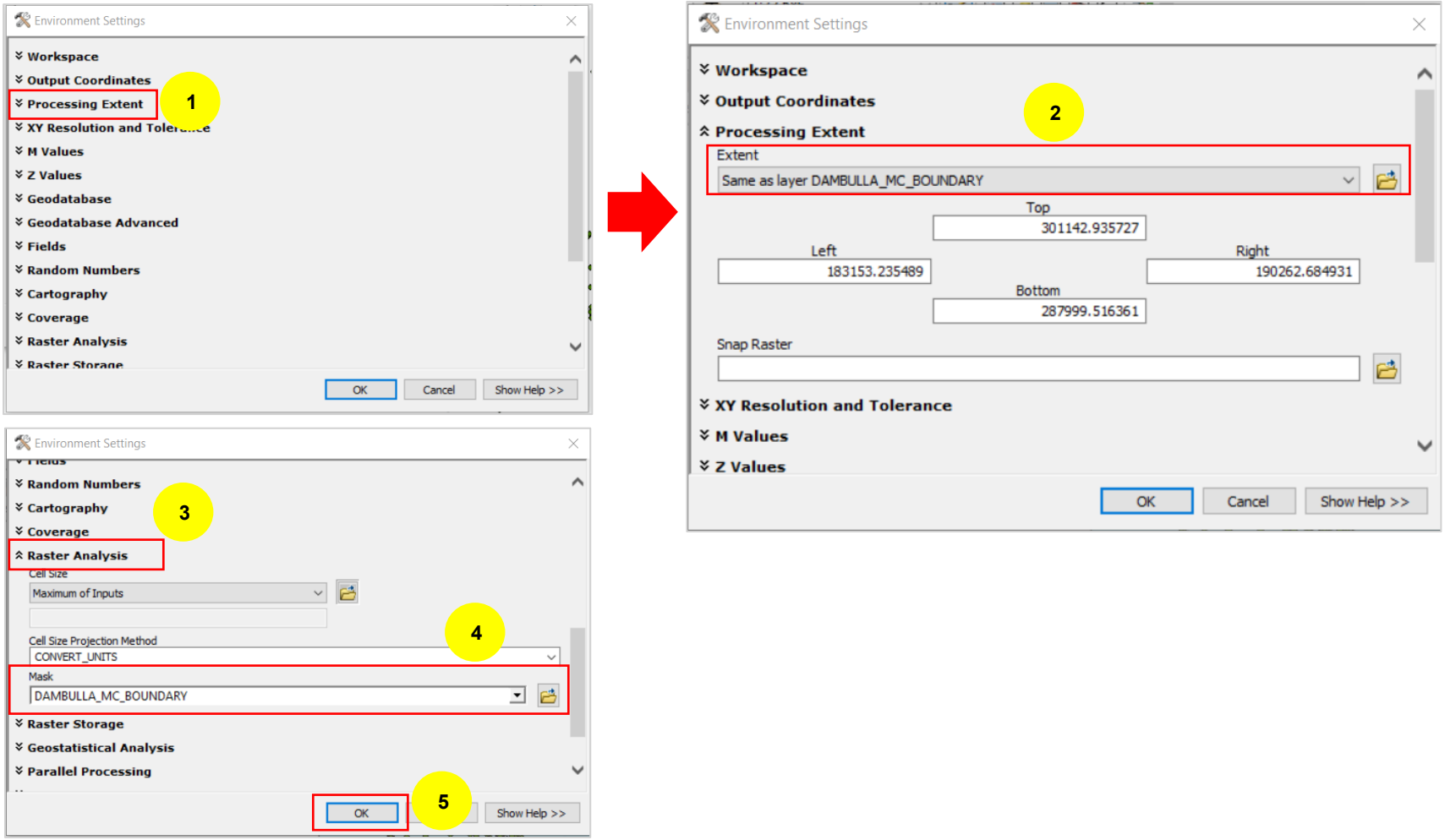
- First, input the point layers into the Arc Map interface.
- Click on the search tab and it will appear the search menu of tools.
- Then type the IDW interpolation in the search bar and click the search icon.
- After searching for the tool, the list of tools will appear under the menu, and select the IDW interpolation (3D Analyst) tool.



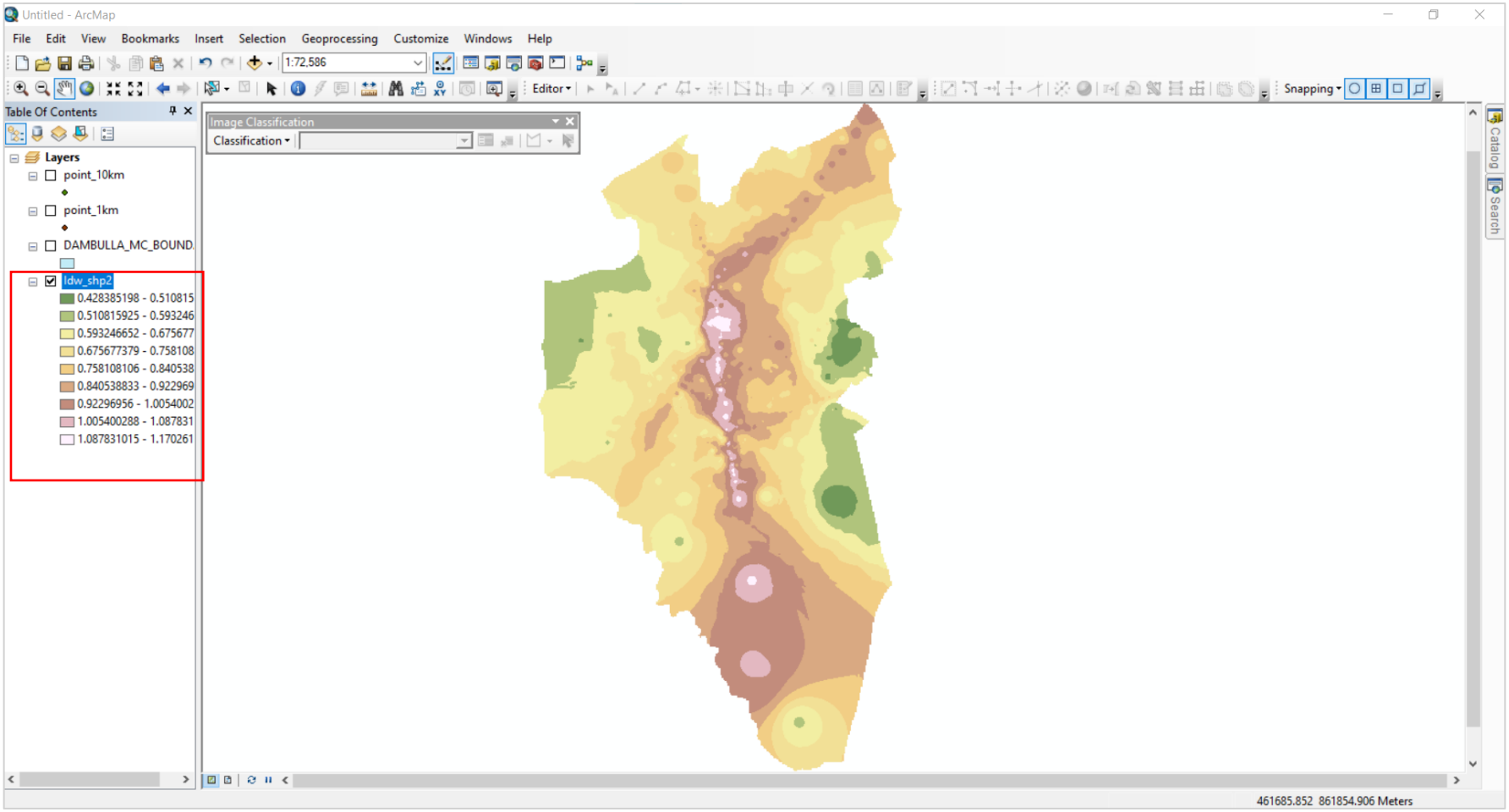
- It will open the IDW tool window and in there select your relevant point layer as the input point features.
- Select **NQPDA 10000** as the z-value field in the drop-down menu.
- Keep output raster as default and click on environments.



- It will open the environment settings window and select the processing extent in there.
- Select your relevant boundary layer as the extent.
- Then click on the raster analysis drop-down menu to open it.
- In raster analysis, select your boundary layer as the mask option and click ok.

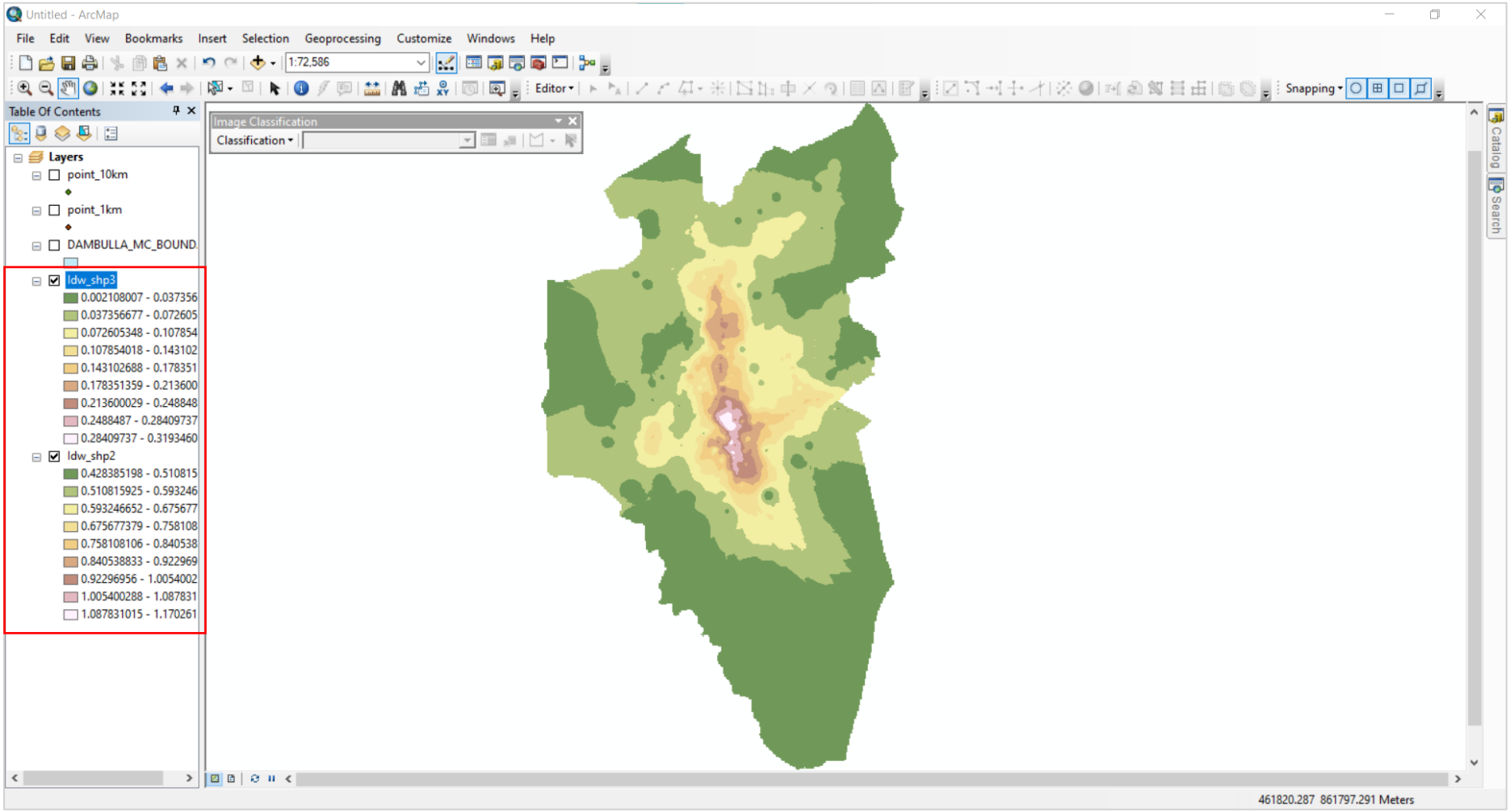


- After running the process, you can get the interpolated point layer of the 10km.

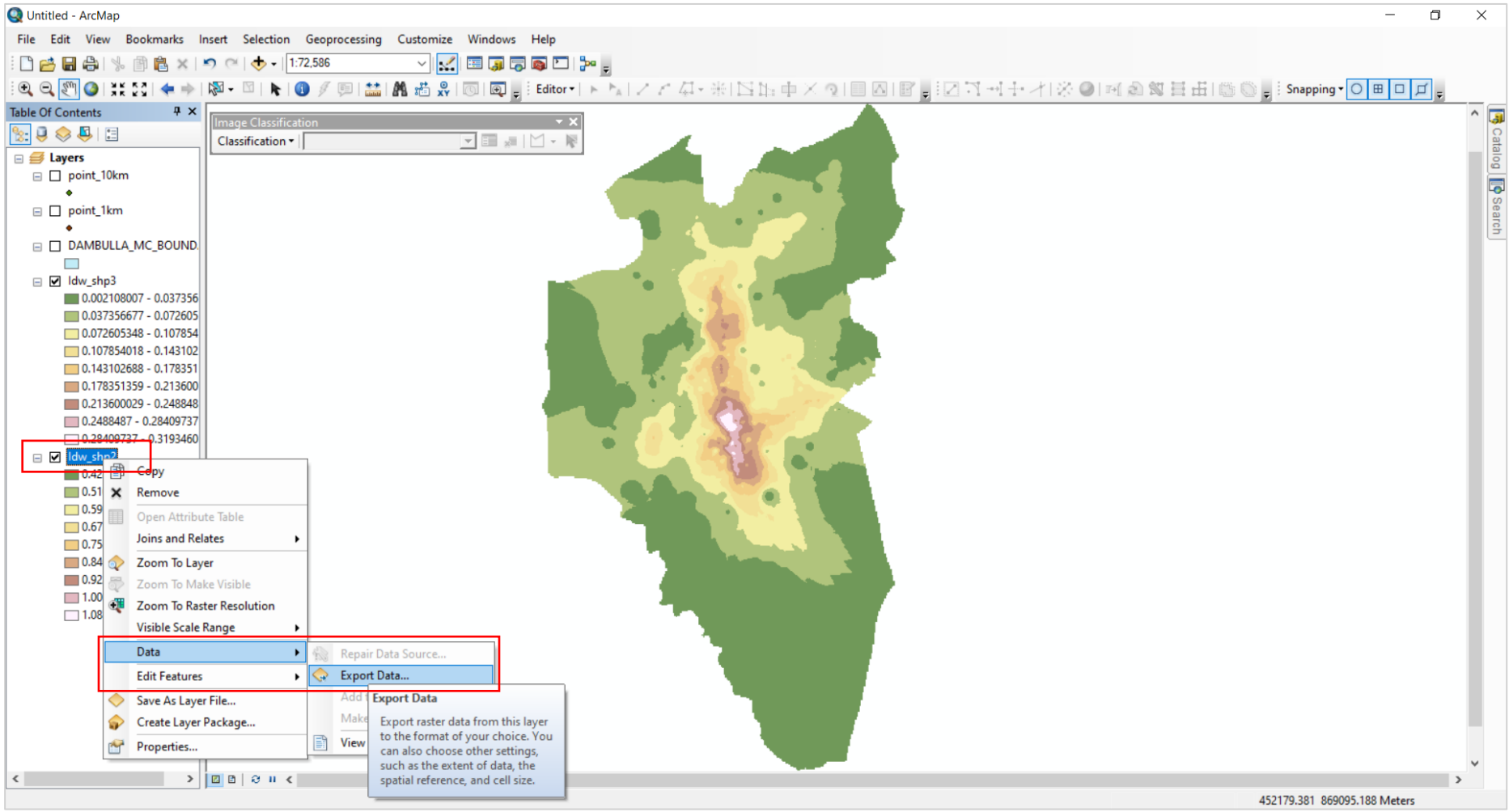


- So, you have to do the same process mentioned above optional steps for your other point layer and interpolate it to obtain a raster dataset. (In this book we have to interpolate the point_1km layer following the same process we have done to the point_10km layer)

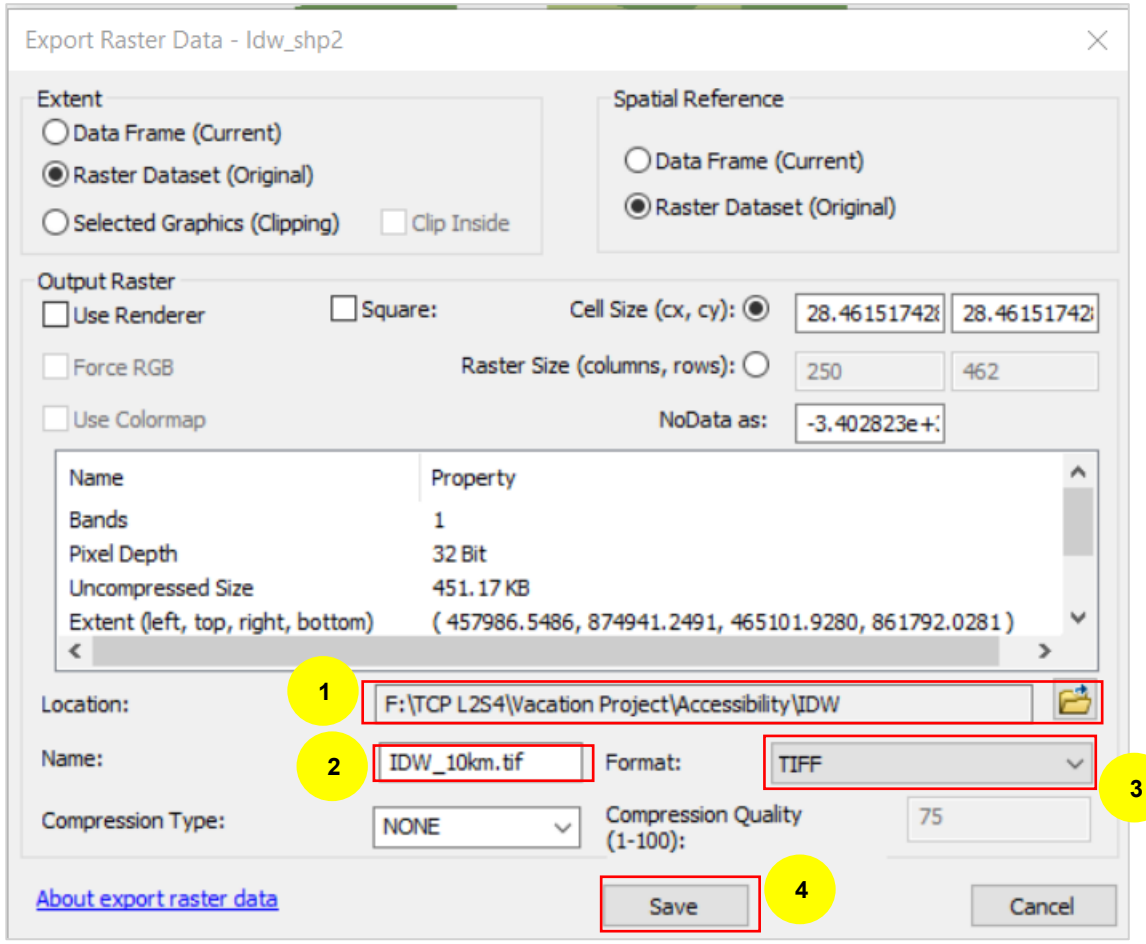
- Now you have obtained two raster datasets for accessibility.



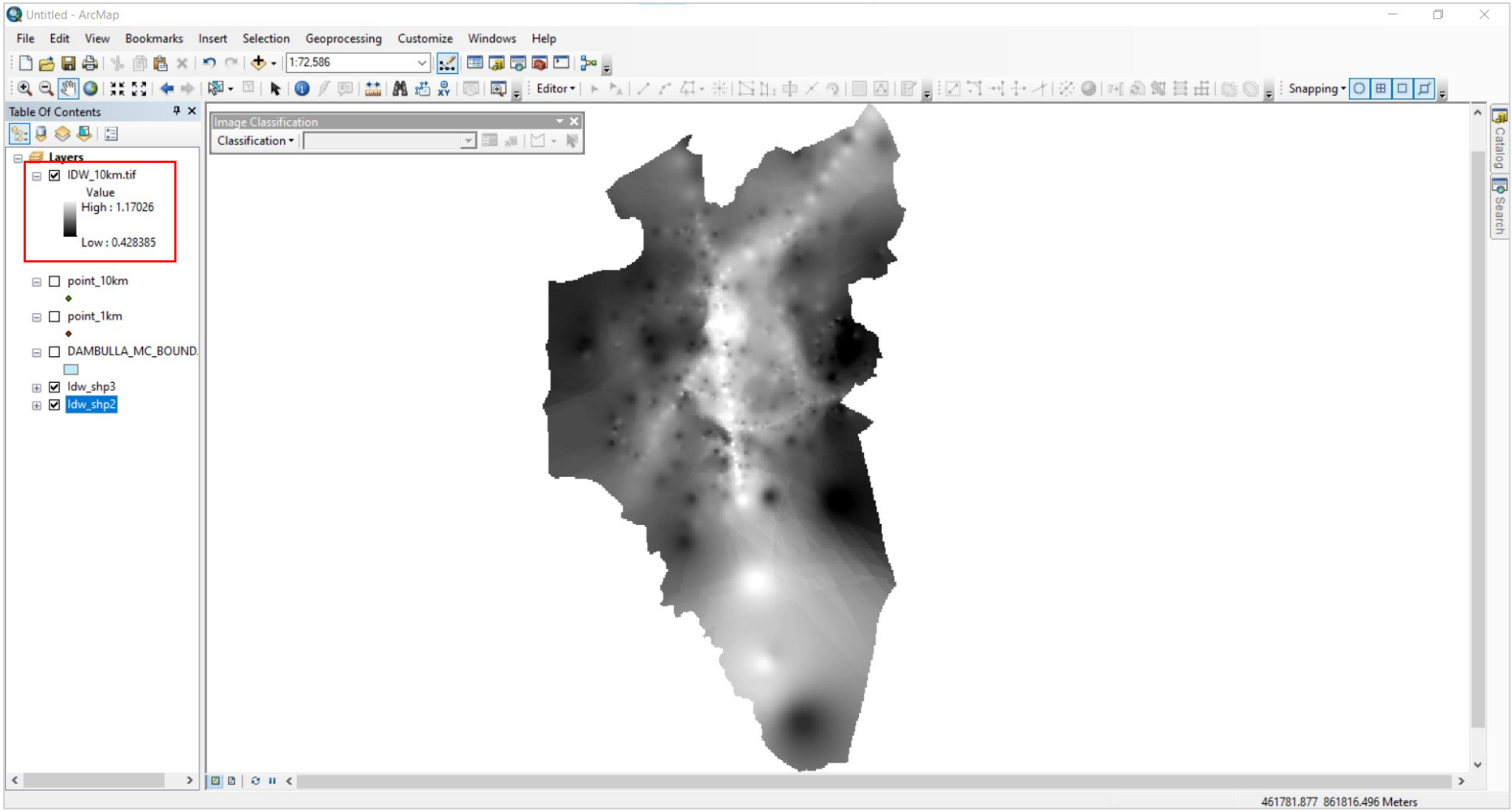
Now you can export them to a folder for easy identification. For that right-click the interpolated layer.Go to the Data and click on export data.



- Export raster data window will appear and in there select a relevant folder to select your data by clicking the folder icon.
- Then give the relevant name. In this book, we gave IDW_10km.
- Select the format as TIFF format.
- Then click on save.

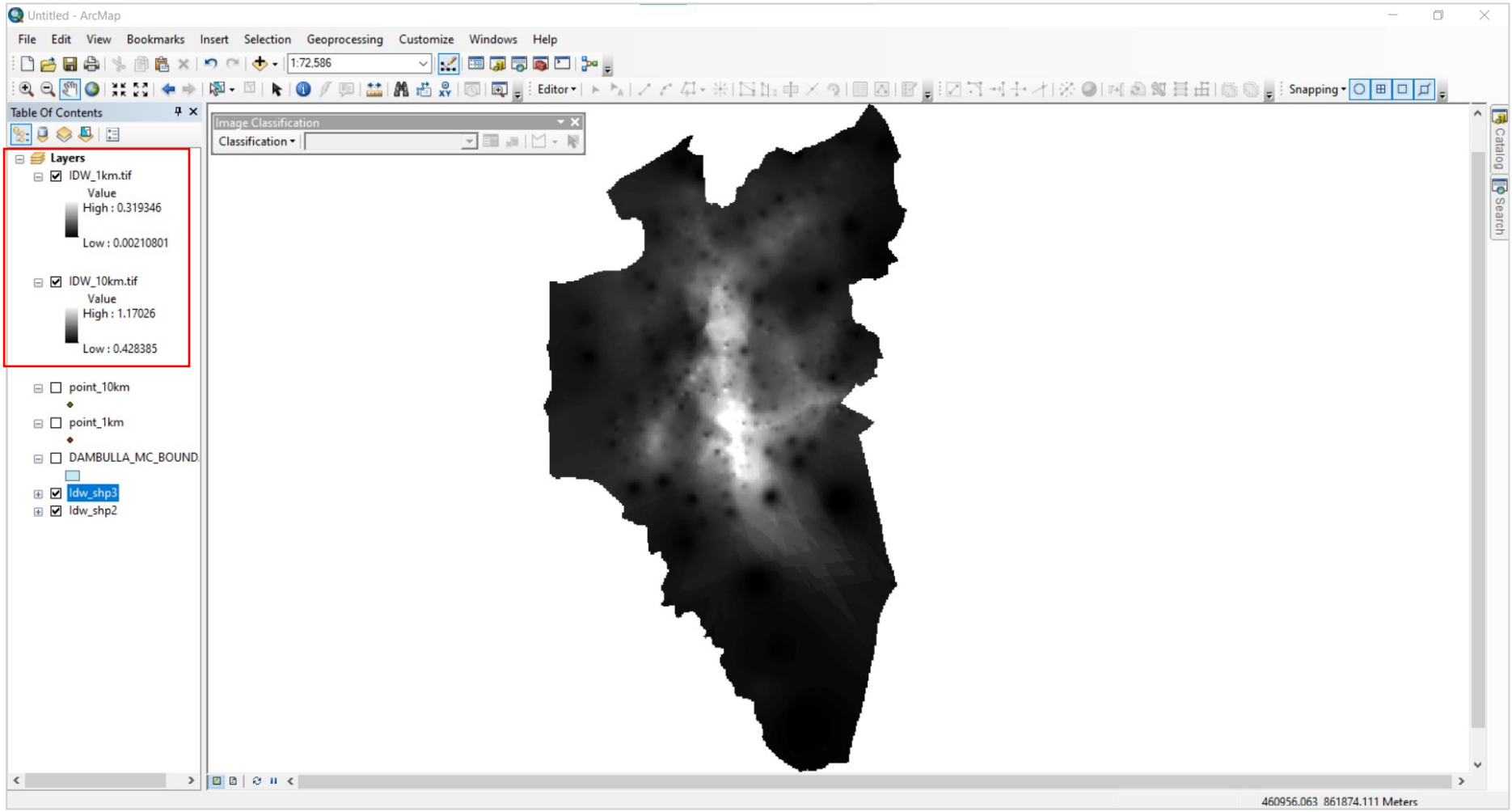


- It will add a new raster layer to the interface and we can use it for further analysis in QGIS.



- Do the same process mentioned in steps 12 to 17 to save the other interpolated layer as well.

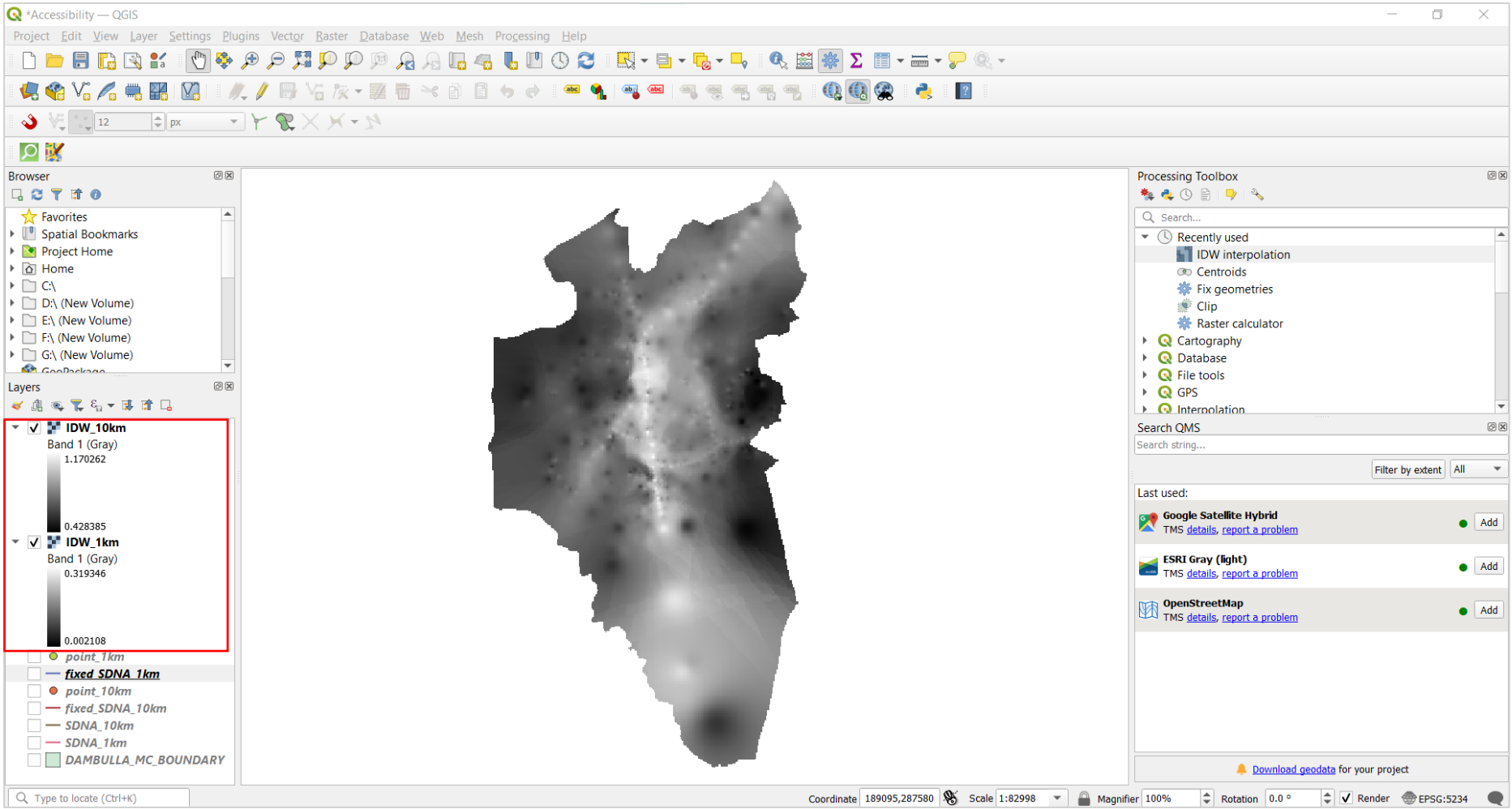
- Now you have the two interpolated layers which can be added to the QGIS interface.



Overlaying the two raster layers

- Again, we are moving to the QGIS. Then we add the above two raster layers into the QGIS.

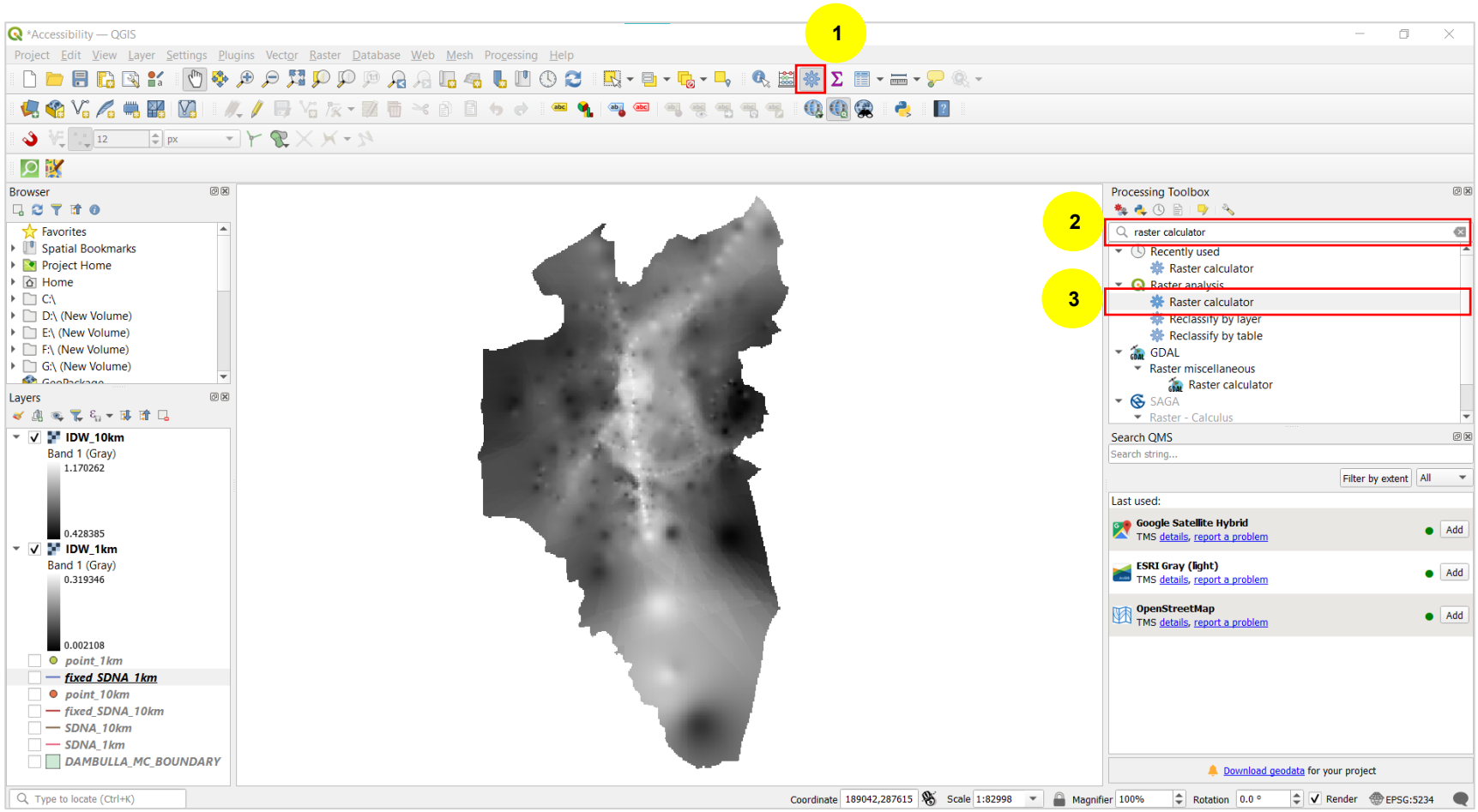
Now the interpolated data are added to the interface of QGIS.



Overlaying the interpolated data using the raster calculator

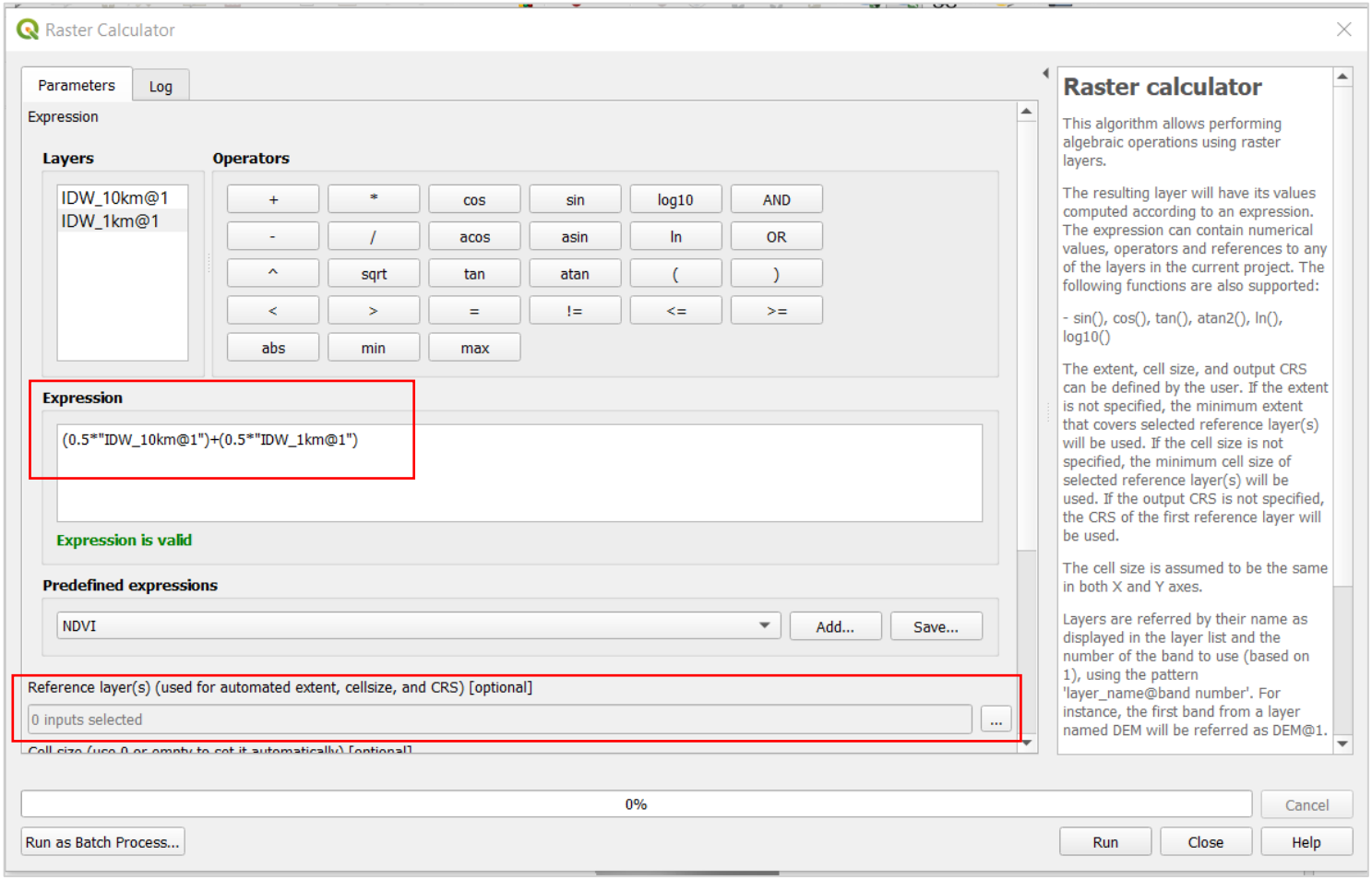
- Click on the processing toolbox icon.

- Type “**raster calculator**” in the processing toolbox’s search bar.
- Once the relevant tool appears, double-click on the raster calculator tool to open it.

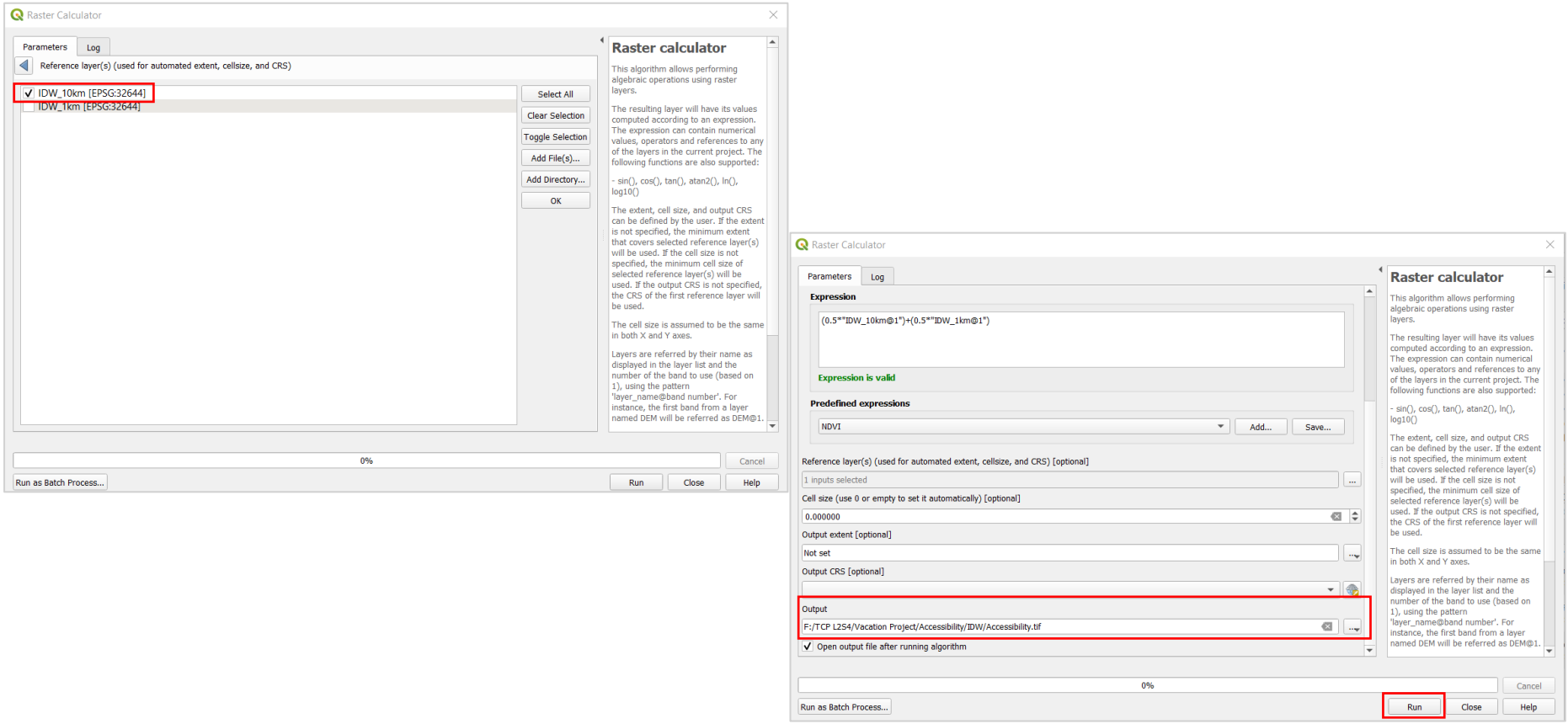


- In the raster calculator window, type the equation in the expression tab. (The two interpolated layers equally contribute to and influence the accessibility level. By dividing 100% influence equally to two we can consider **0.5** as the weight factor for these two layers as they equally contribute to the accessibility level. So, we have to multiply each layer from **0.5** to get the accessibility level)

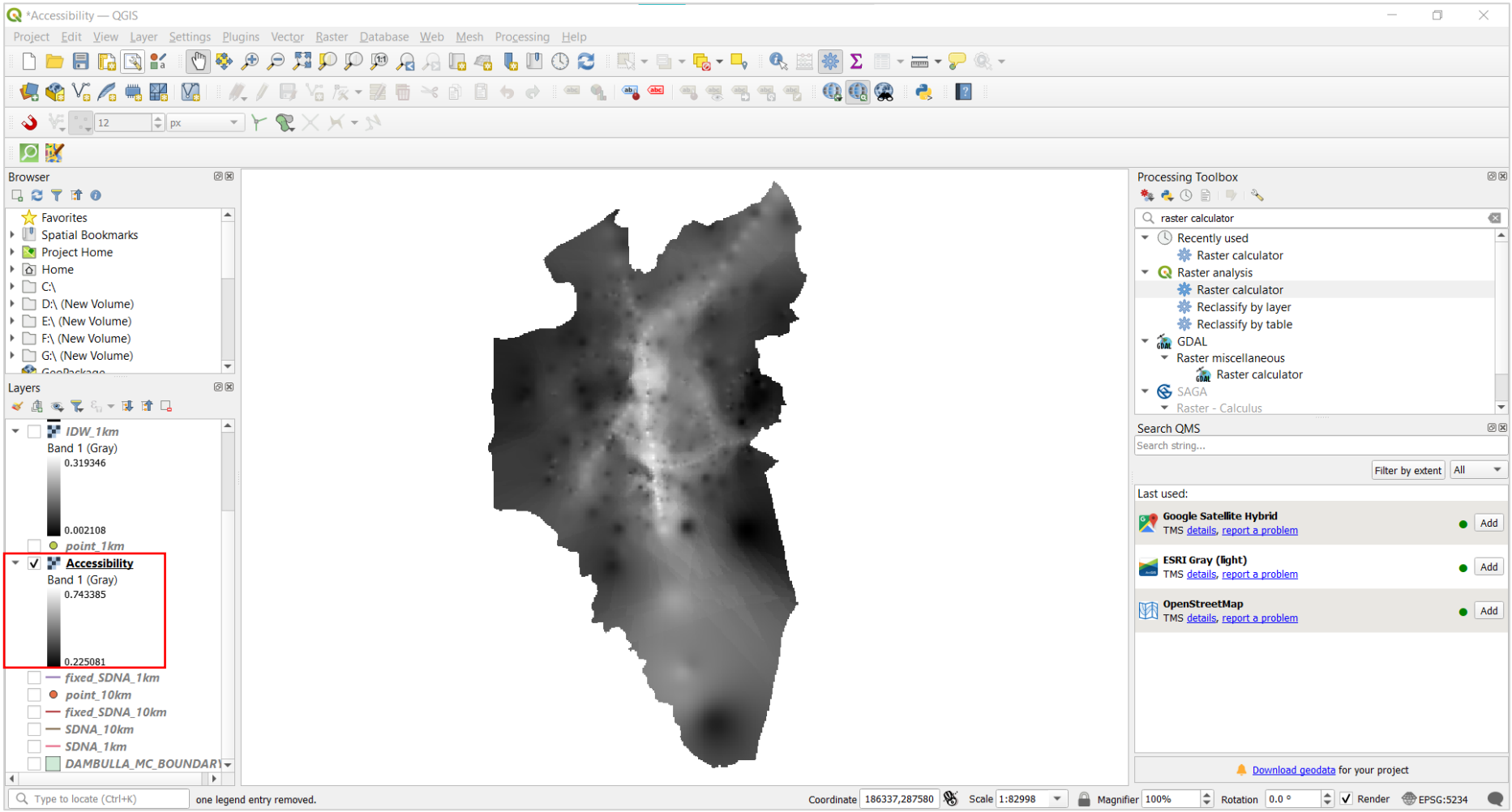
- Then click on the three-dotted icon to select a reference layer.



- In the reference layer, select one of the layers and go back to the previous window. By accessing the reference layer, it will automatically assign the coordinate system, cell size, and output extent of the selected layer to the output layer.
- So, there is no need to change the other parameters in the raster calculator and select a relevant folder to save the accessibility raster file.
- Then click on run to overlay those two rasters.

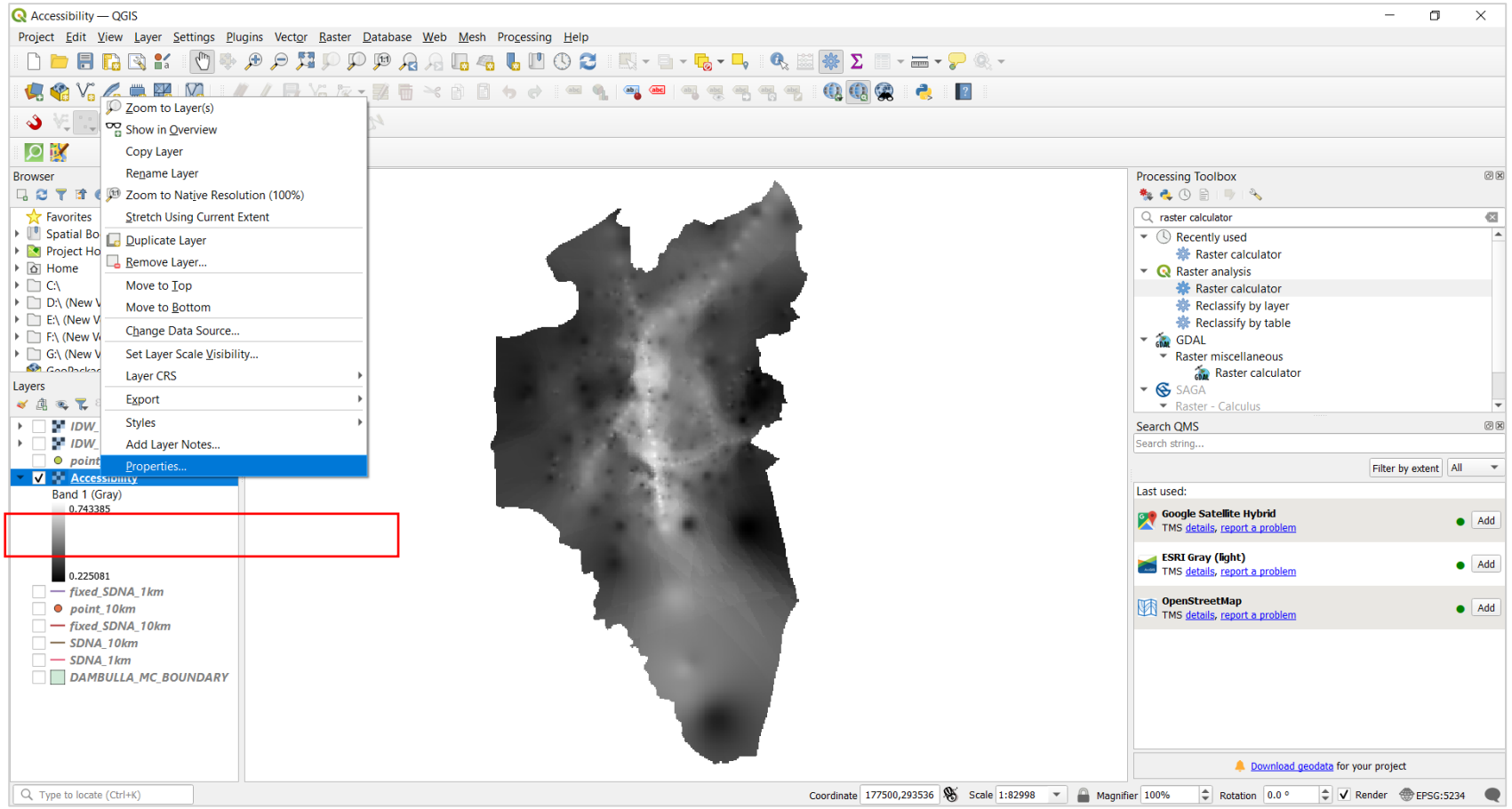


So, you got the accessibility raster layer by overlaying the two interpolated layers.



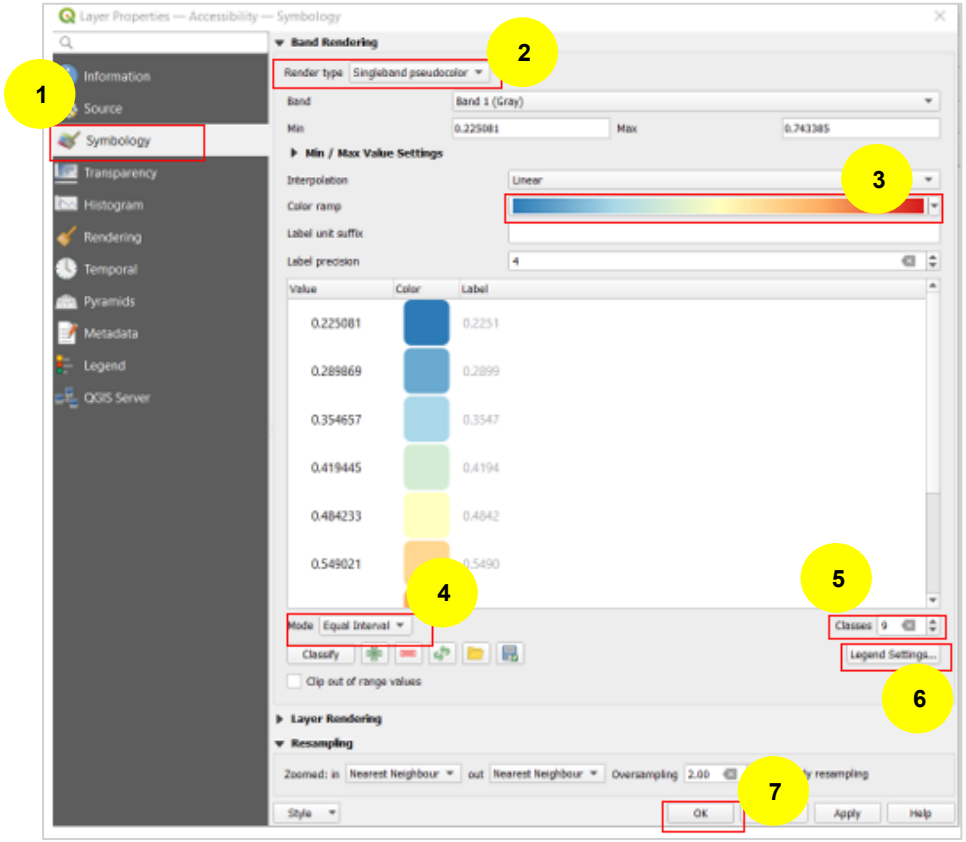
Get the accessibility raster layer

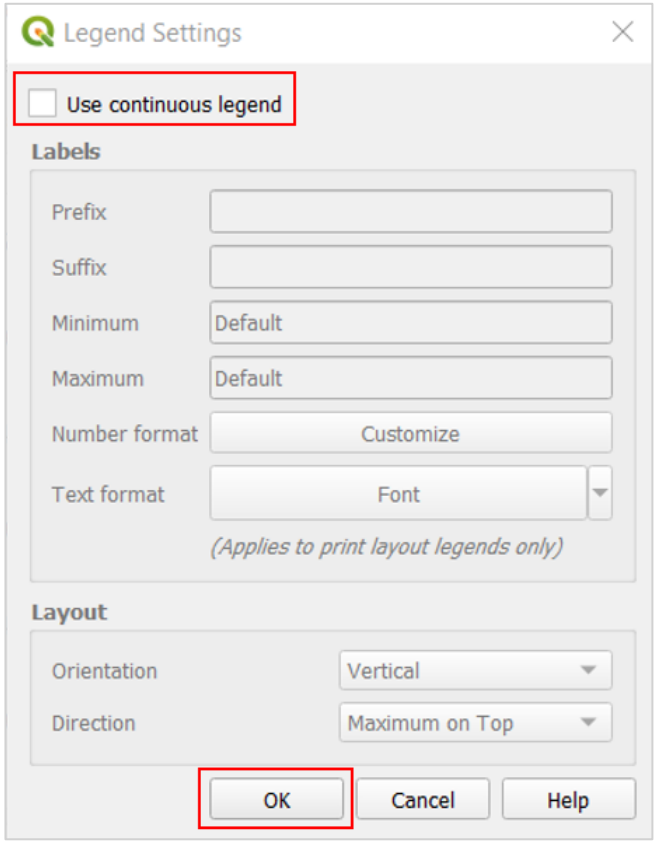
- Right-click on the accessibility layer and go to the properties.



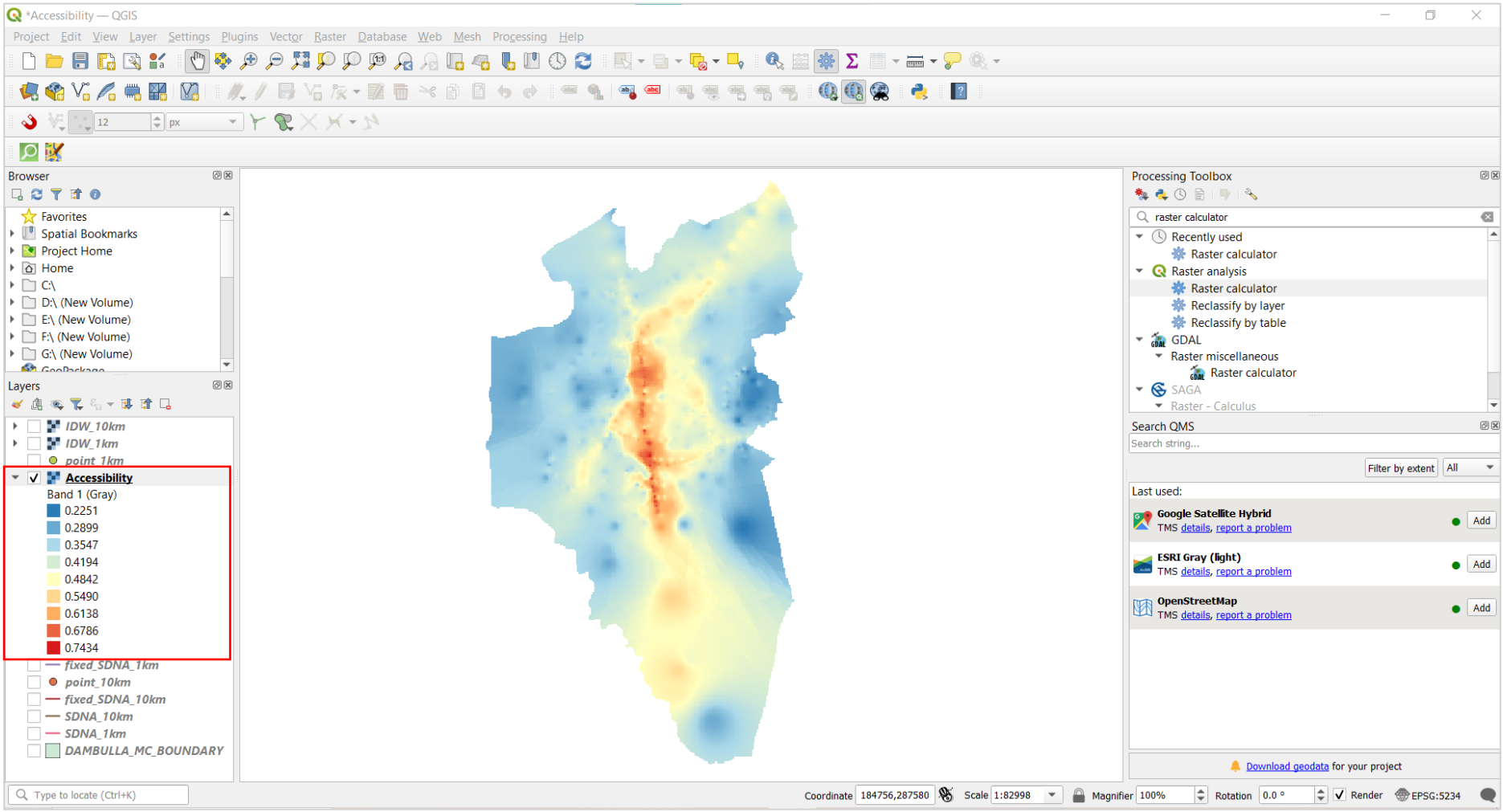
- Go to the symbology panel and select the render type as “**singleband pseudocolor**”.
- Then select a relevant color ramp.

- Set “**equal interval**” as the mode.
- We can categorize accessibility into 9 classes, so type “**9**” in the classes.
- Then click on legend settings.
- In the legend settings window tick off the use continuous legend and click “**OK**”.
- After applying all parameters click “**Apply**” and “**OK**”.





- Now you can get the accessibility level raster layer.



CHAPTER 3: MOLUSCE PLUGIN TO MODEL THE FUTURE LAND USE CHANGE

What is MOLUSCE?

MOLUSCE (Modules for Land Use Change Simulations), is a robust QGIS plugin meticulously designed to analyze and predict the future land use change within specific regions. Employing a suite of algorithms encompassing Artificial Neural Networks (ANN), Logistic Regression (LR), Weight of Evidence (WoE), and the Markov Chain Ensemble (MCE) method, MOLUSCE excels in simulating and evaluating land use alterations over time. By ingesting raster data representing historical and current land use categories alongside pertinent explanatory variables, including socio-economic factors, the plugin seamlessly conducts model training to forecast future land use changes. With applications spanning urban planning for evaluating urban growth and development, forestry for predicting alterations in forest cover, and environmental impact assessment, MOLUSCE emerges as an indispensable tool for comprehensive land use analysis and informed decision-making.

Modeling capabilities

MOLUSCE boasts extensive modeling capabilities by incorporating diverse driving factors crucial for understanding land use dynamics, including proximity to roads, distance to urban centers, slope, environmentally sensitive areas, land use efficiency, population density, etc. By integrating these factors into its predictive models, MOLUSCE accurately forecasts future land use changes based on the provided data. Furthermore, the plugin offers validation tools such as kappa statistics to evaluate the performance of these predictive models, ensuring reliability and accuracy in assessing and predicting land use transformations over time.

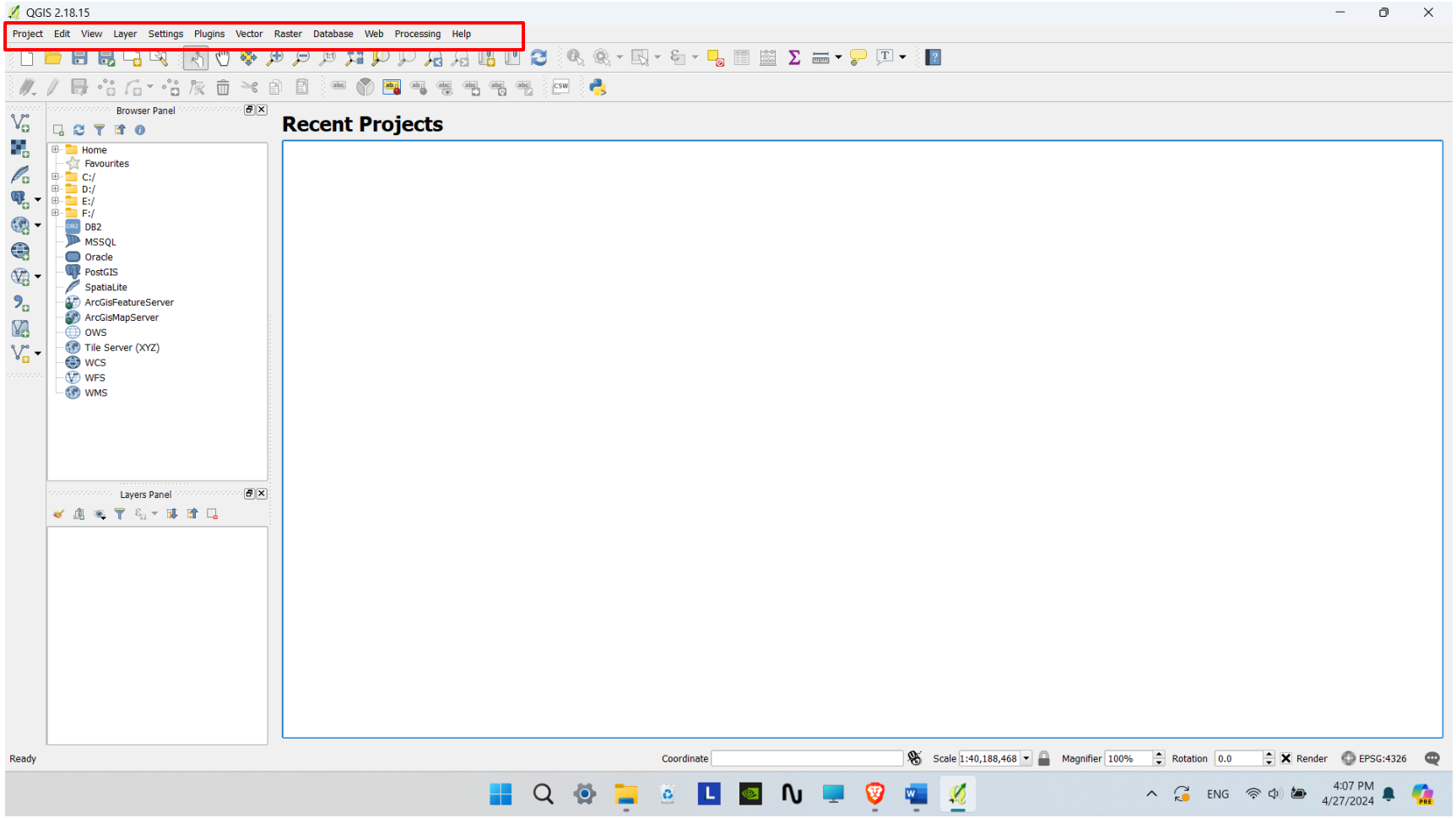
The maximum number of inputs for factors in the MOLUSCE plugin can vary depending on several factors, including the computational resources available and the complexity of the model being used. While there is no fixed maximum limit specified, MOLUSCE is designed to handle a wide range of input variables, allowing for a comprehensive analysis of land use changes. The actual maximum number of inputs may be determined by practical considerations such as available memory and processing power.

Compatibility and Installation

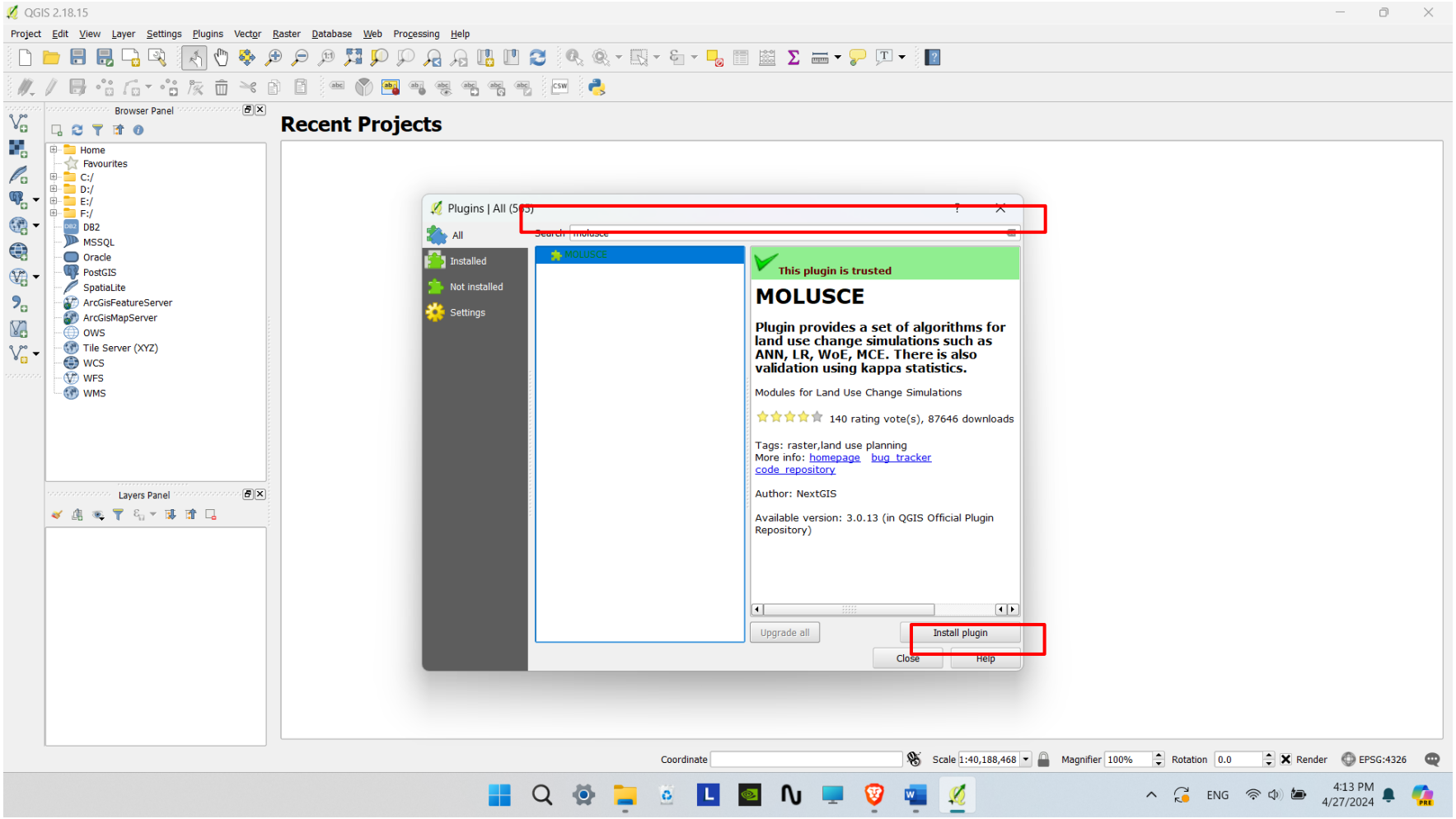
MOLUSCE is compatible with QGIS, specifically versions 2.0 and above. QGIS 2.18 is usually used for this purpose. This is open-source software, and after downloading the setup, you can install QGIS 2.18 on your computer in a few simple steps.

This version is compatible with Windows XP 64-bit, Vista 64-bit, Windows 7 64-bit, Windows 8 64-bit, Windows 10 64-bit, Windows 11 64-bit operating systems. While there are no strict formal requirements, it is recommended to have a minimum of 4 GB of RAM to ensure smooth operation, with additional RAM greatly enhancing processing speed, particularly for handling large datasets and complex analyses. While QGIS itself is not highly graphics-intensive, having a decent graphics card with OpenGL support can improve map rendering, 3D visualization, and overall system responsiveness, enhancing the user experience when utilizing MOLUSCE for comprehensive land use assessments and simulations.

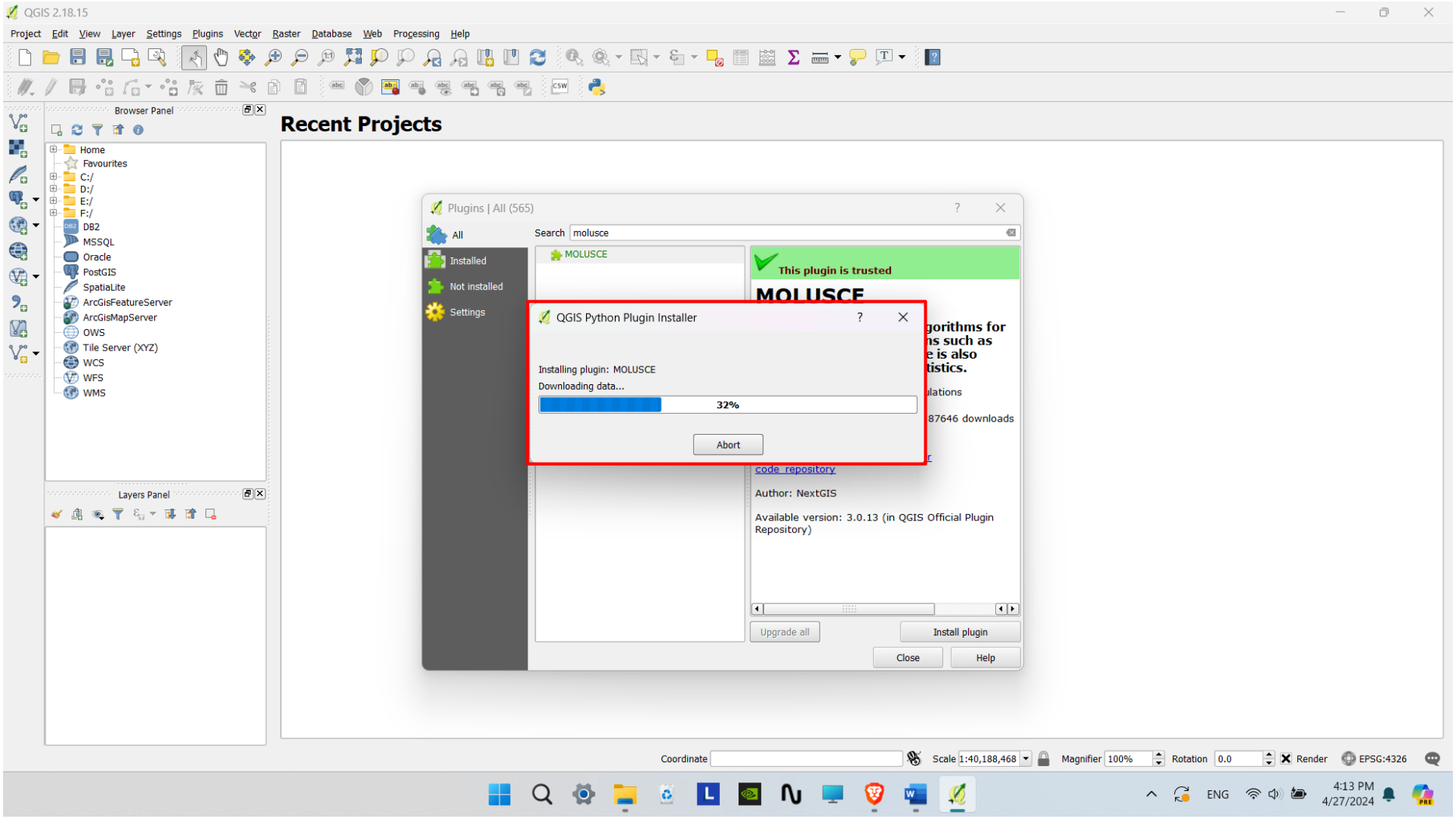
1. After installing QGIS 2.18.15, we have to install the **MOLUSCE plugin** separately. For that, open the QGIS software. The interface looks as follows. You can see the main toolbars in the left upper corner of the interface.



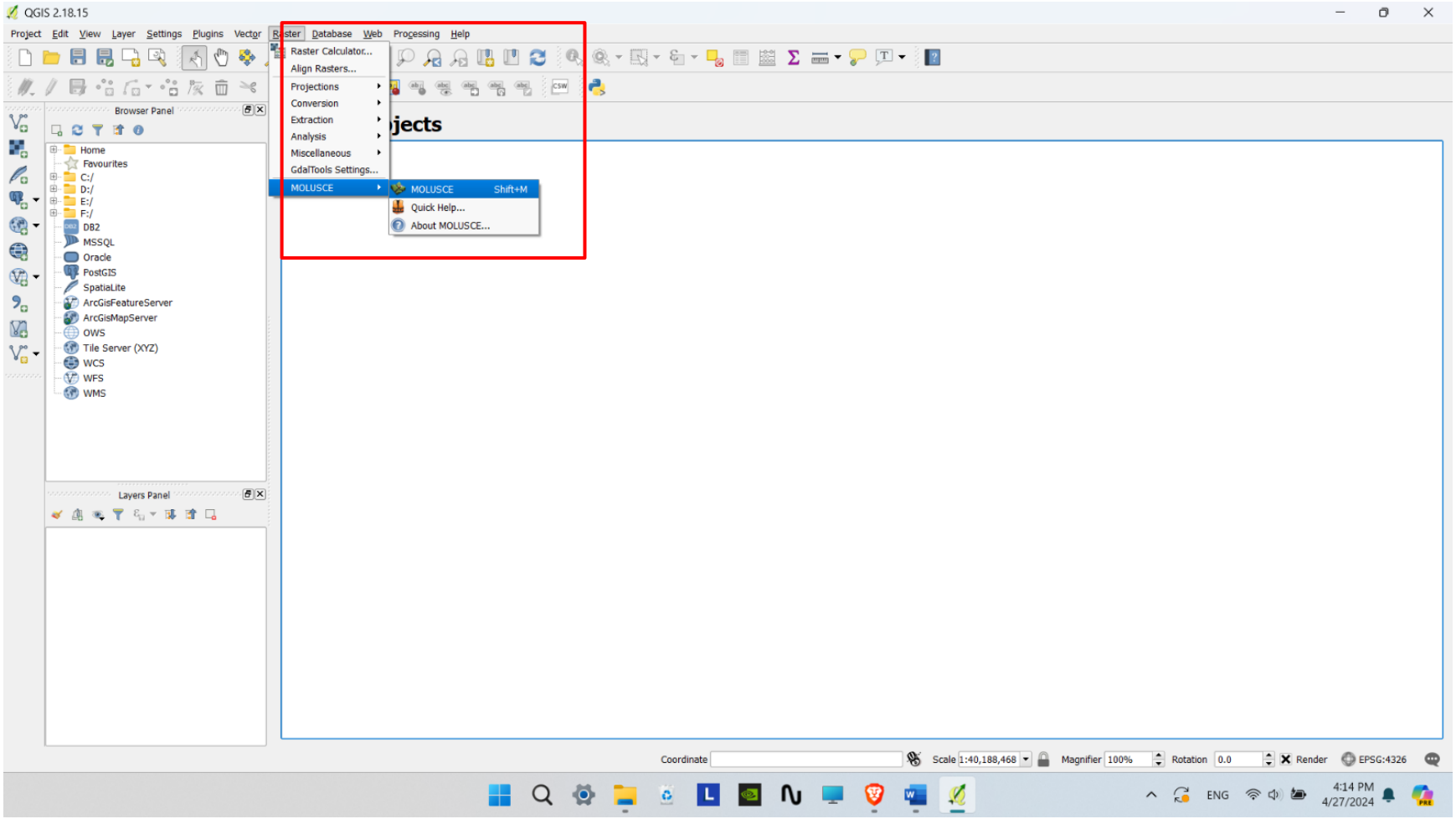
2. Next, we have to install the MOLUSCE plugin. For that, open the Plugins toolbar from the left upper corner, and search for the MOLUSCE plugin as follows. Then the plugin will be shown. After that, click on “**Install plugin**” to install this plugin.



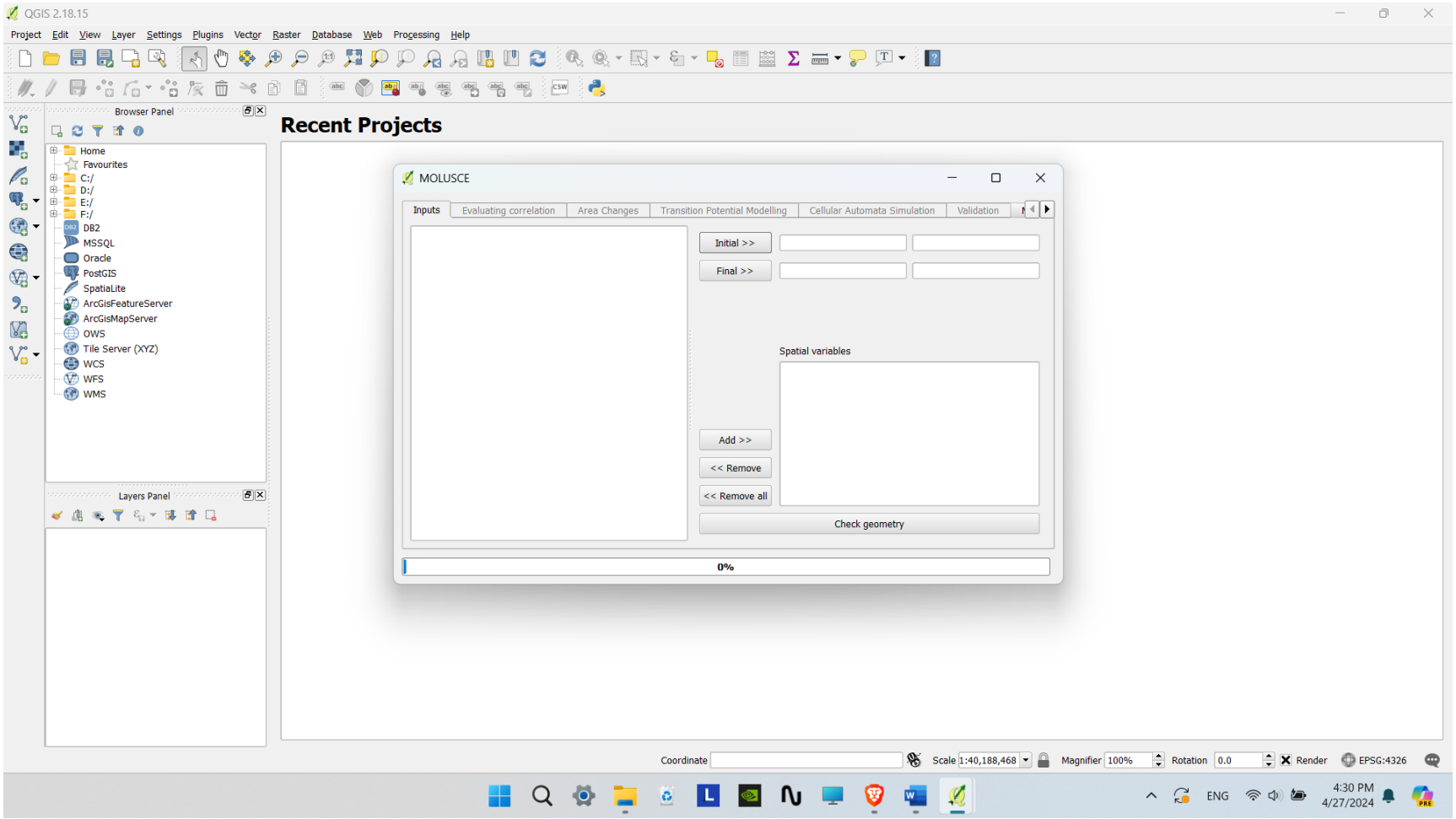
3. The installation process will be shown as follows. Once this process is complete, you can close the plugin's toolbar.



4. Now you can click on the Raster toolbar. It contains several tools and the MOLUSCE plugin as follows. Then again click on the "**MOLUSCE**". Finally, the plugin and its related tools will be shown.

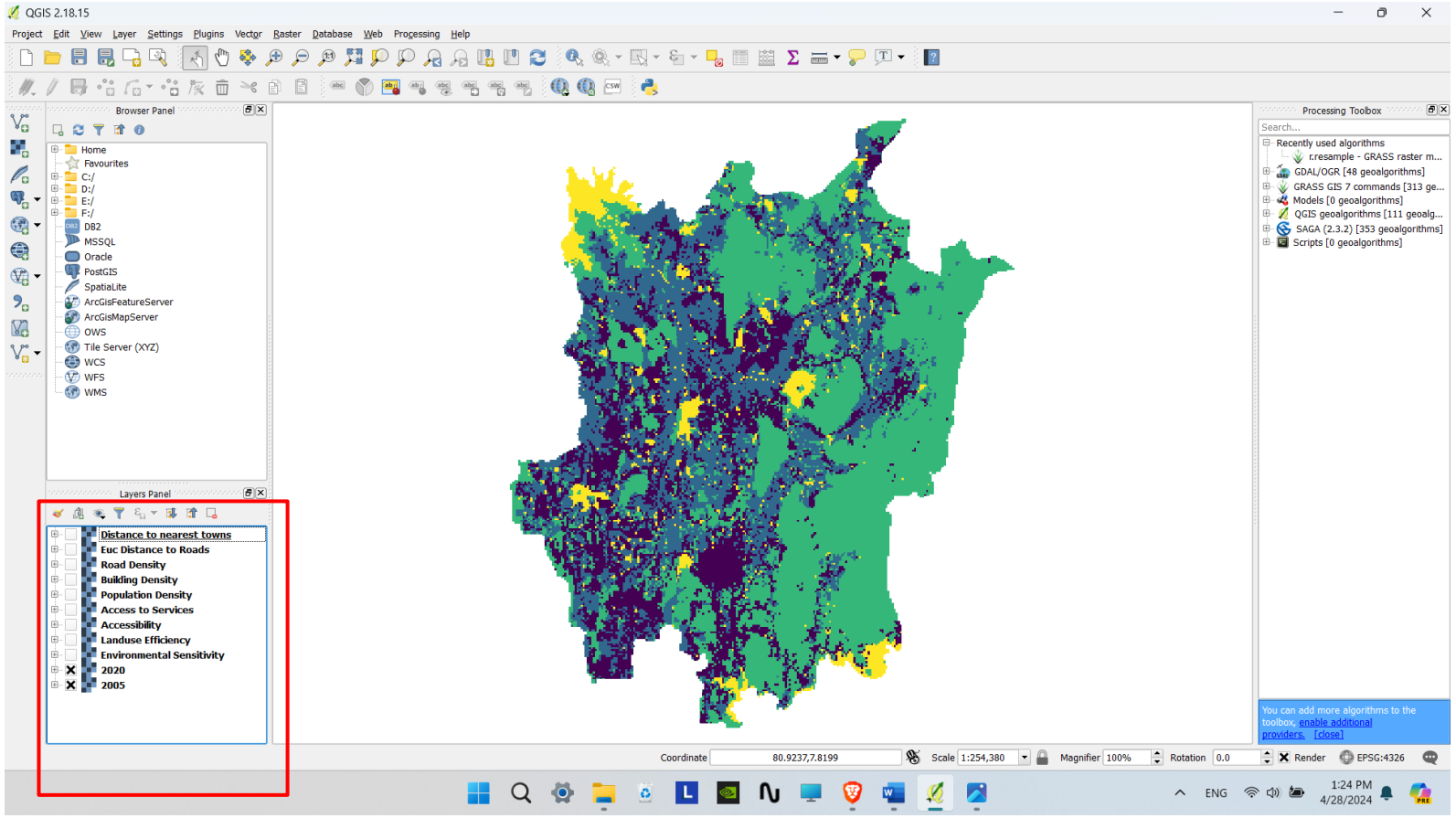


5. Click on the “**MOLUSCE**” and open the plugin now. The plugin will appear in the following way.

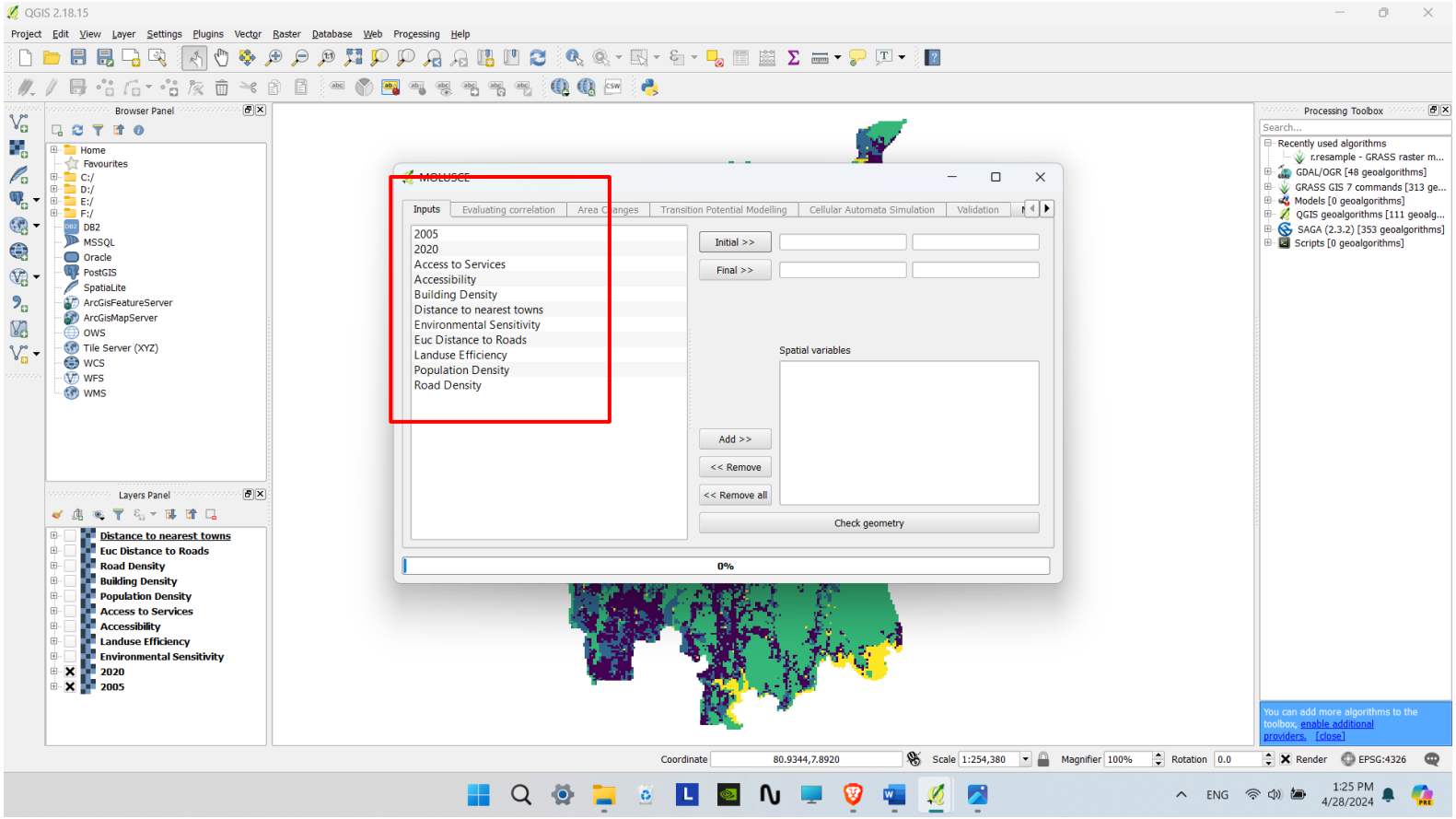


3.1 Modeling process with MOLUSCE

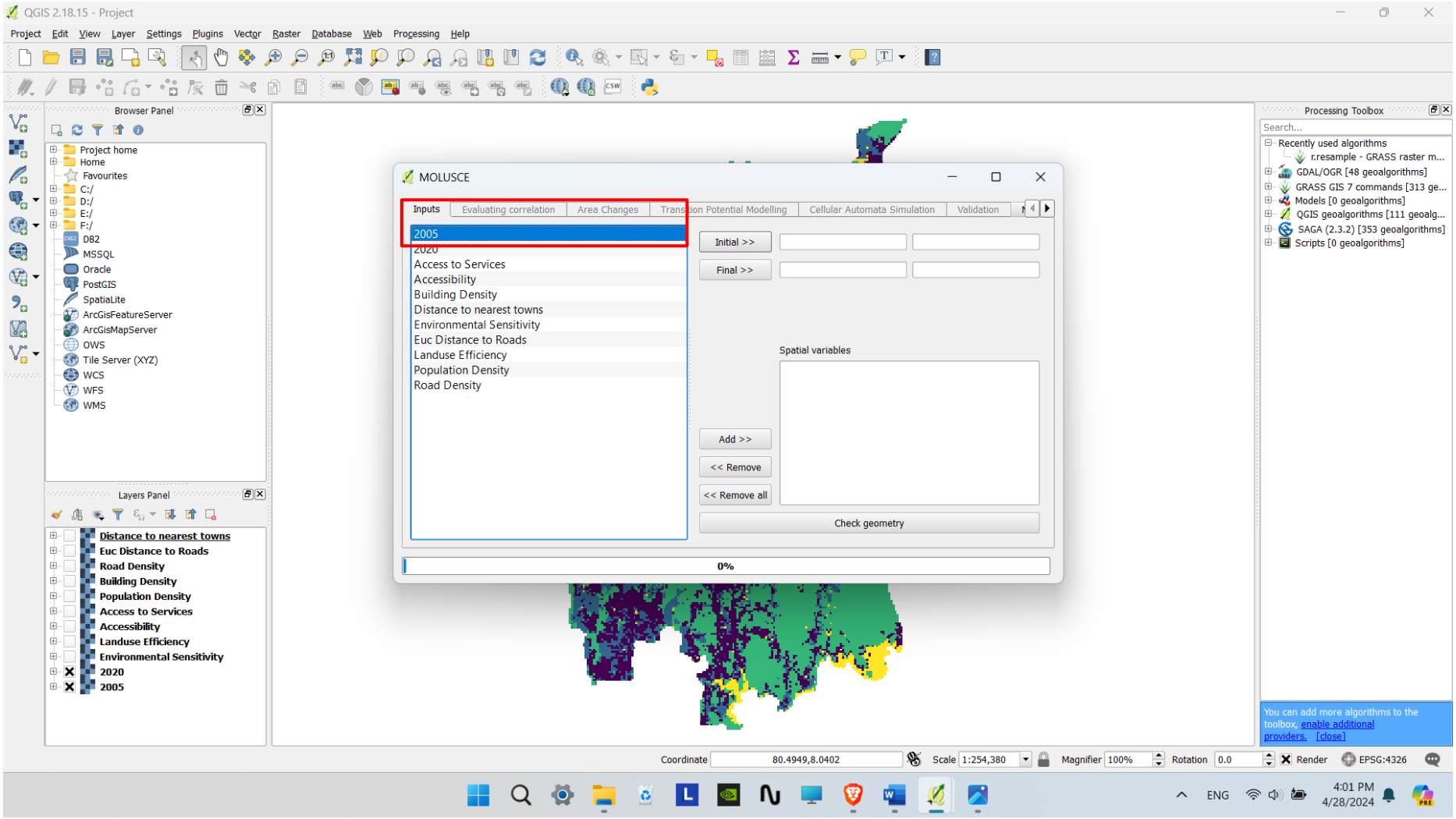
All the land use layers and layers for the spatial variables should be imported to the QGIS. Then, you can see that the **Layers Panel** contains all these layers. Next, we can proceed with the MOLUSCE plugin.



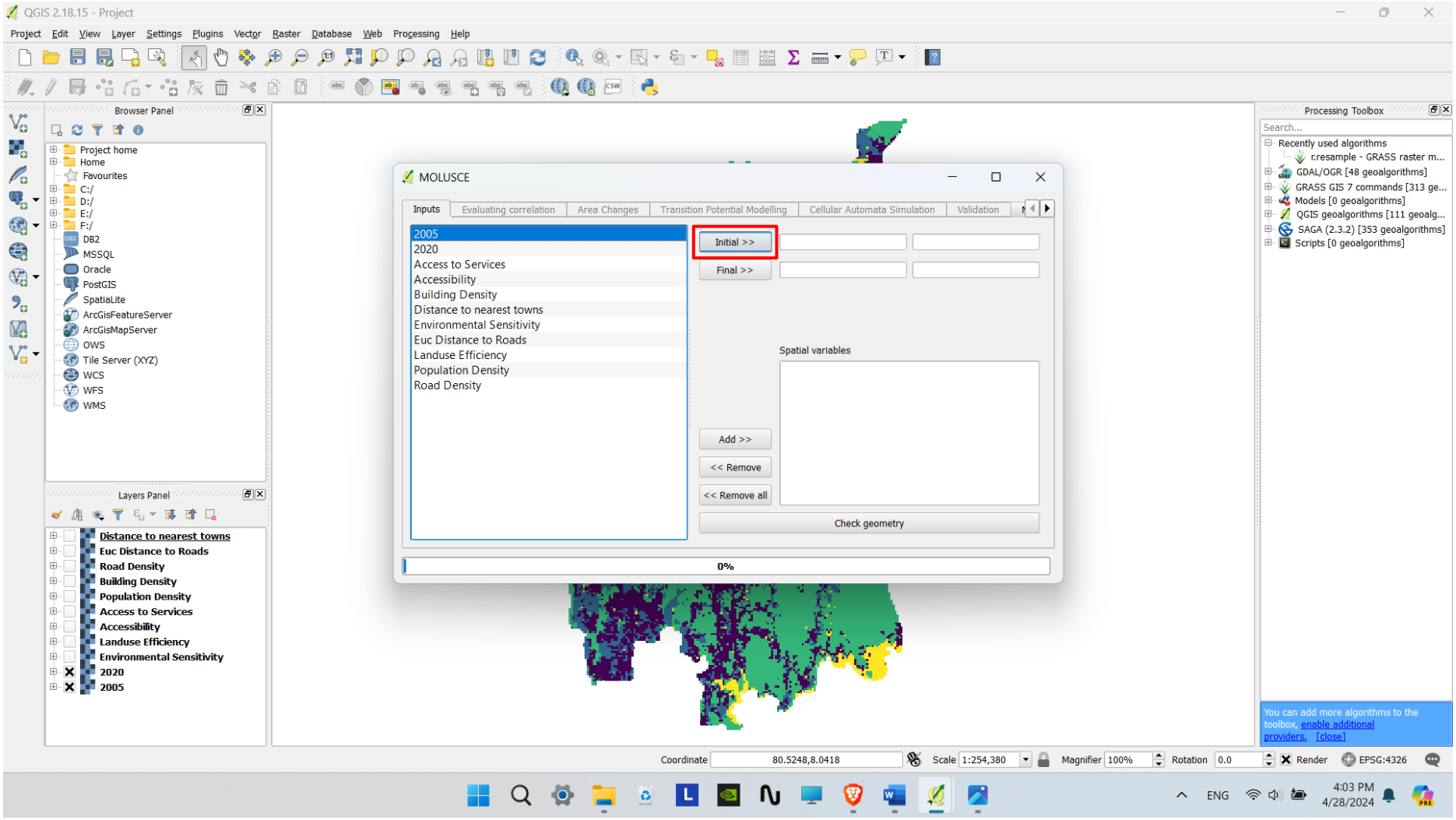
Open the MOLUSCE plugin from the Raster toolbar. You can see all the layers in the project are shown in the "**Inputs**" tab here. The next step is to insert layers into the model as required. This plugin is very easy to use, and for this, it is important to set up the layers we use correctly. To predict the future land use change, the land use layers of two years should be used. The historical land use layer as the **initial layer** and the current land use layer as the **final layer** should be given here as inputs.



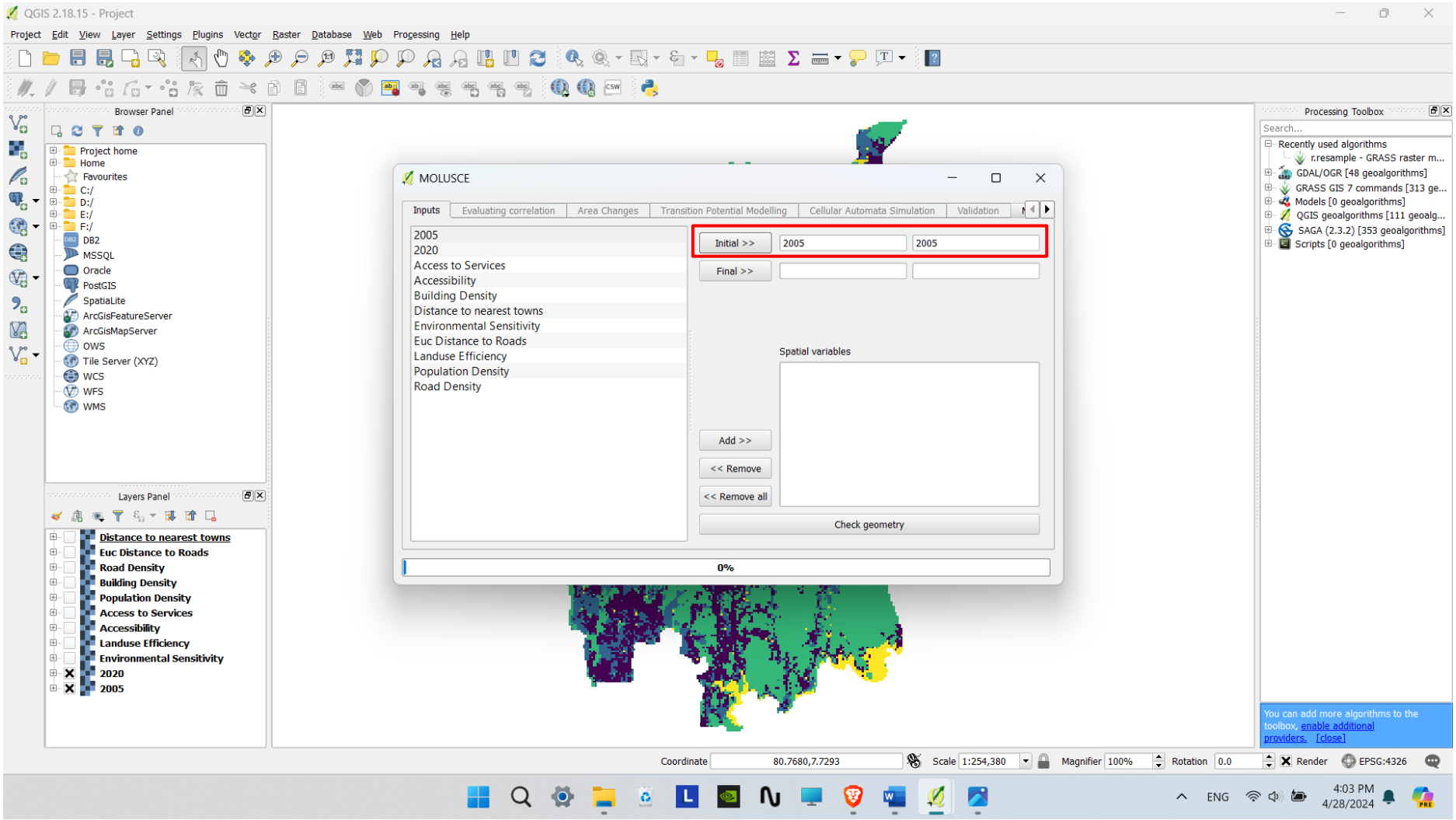
First, we have to add the initial layer. According to this project, the initial layer is the 2005 land use layer. Now click on "**2005**" to select the initial layer.



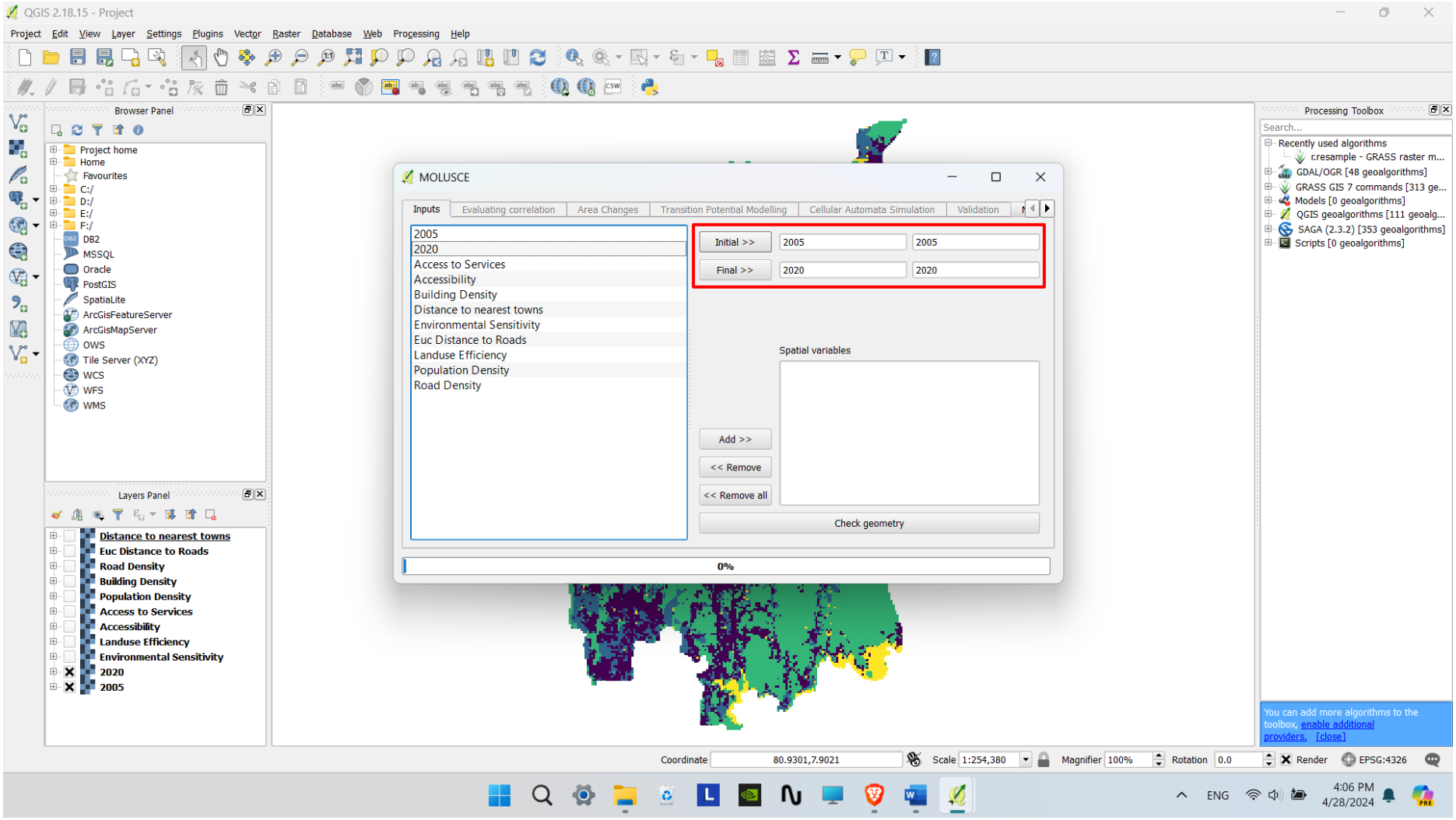
Then, click on the “**Initial**” button to add the selected layer to the model.



The initial layer was successfully added to the model. It is shown as follows.

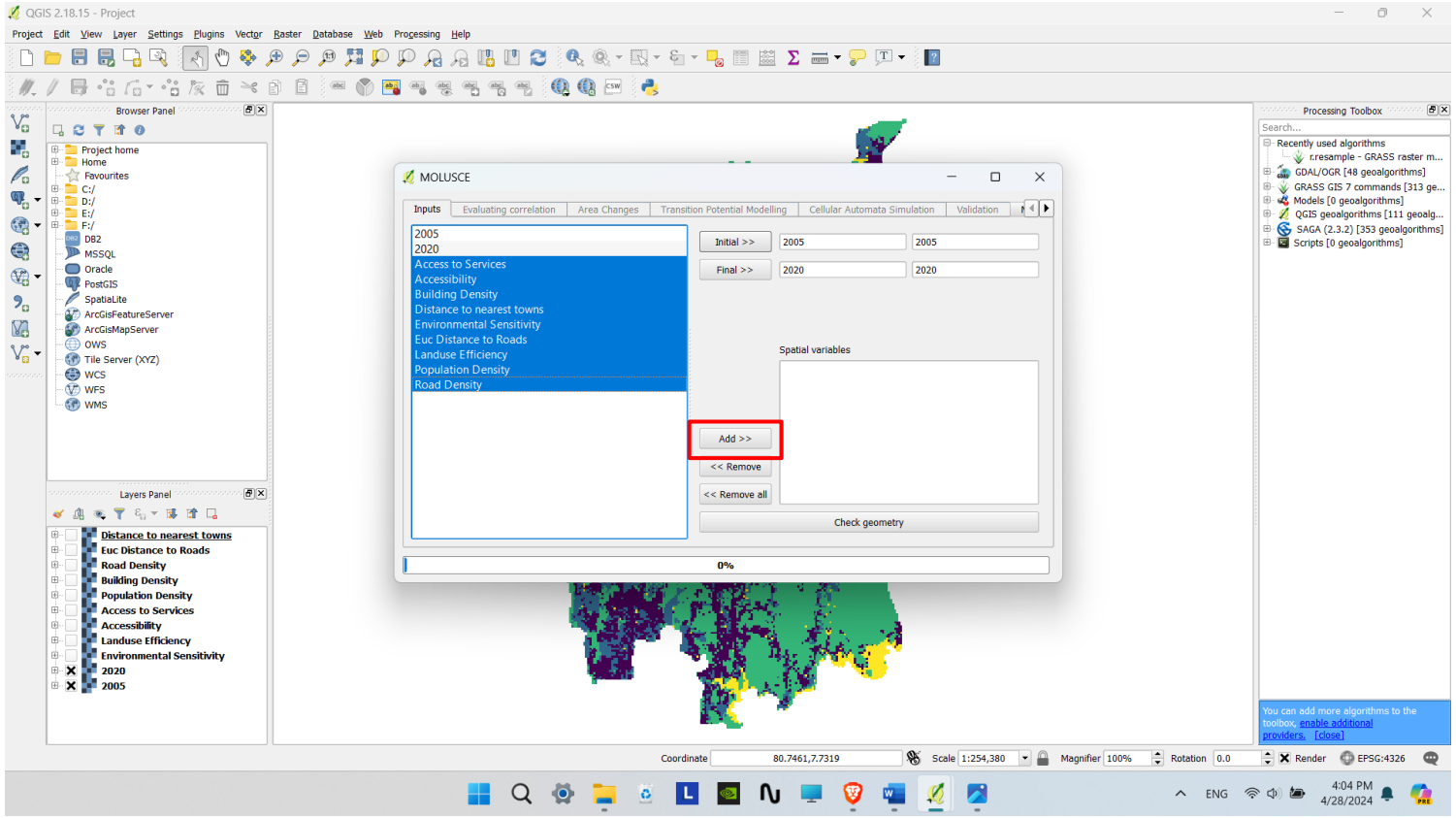


With the same steps, you can add the Final layer to the model. In this scenario, our final layer is the 2020 land use layer. Click on “**2020**” and proceed.

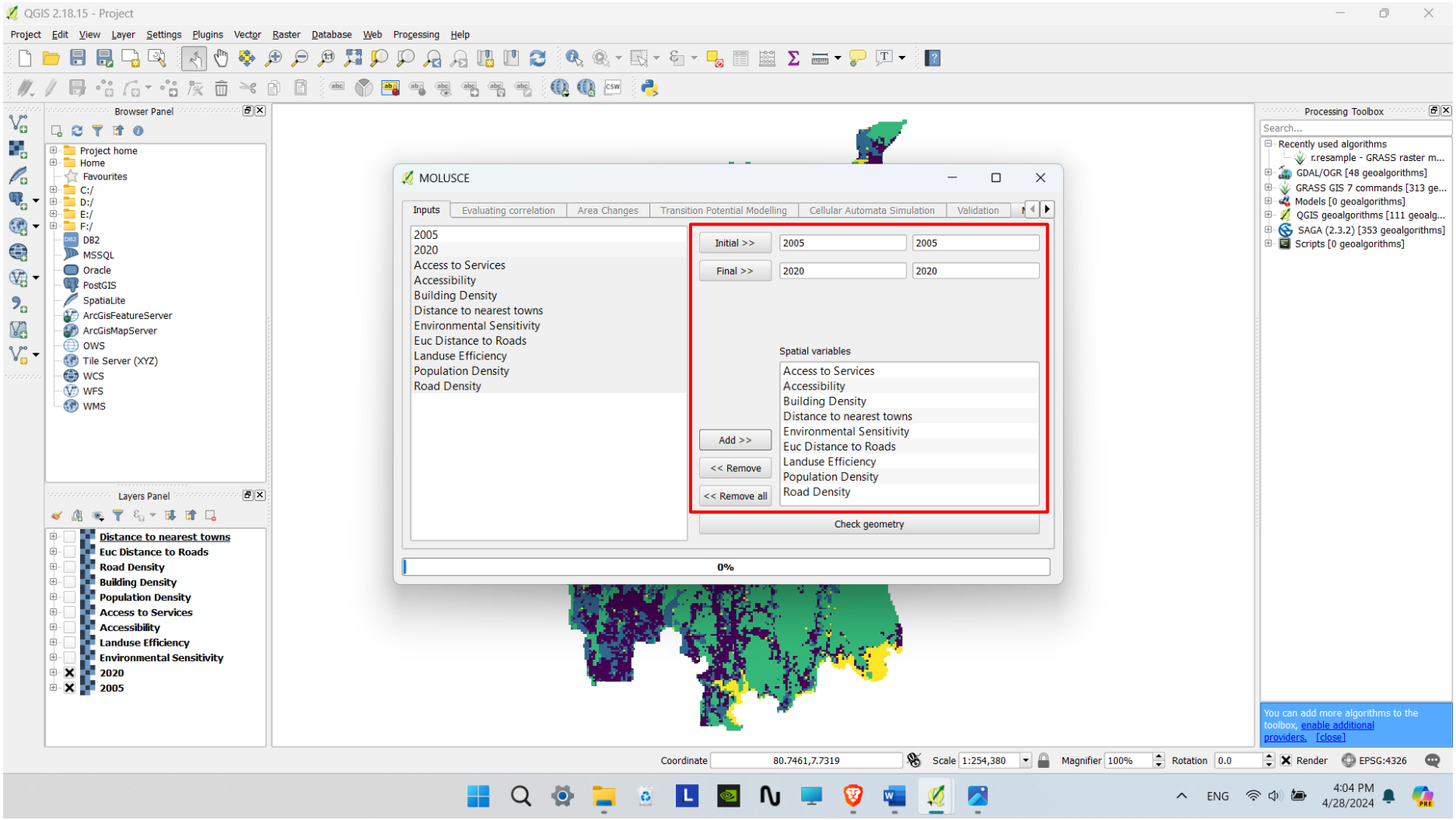


In the next step, you have to add the spatial variables to the model. Here we consider the factors that affected the land use change in the period we consider above. That is how the future land use change is predicted through this plugin. The layers related to those factors should be added here under **Spatial Variables**.

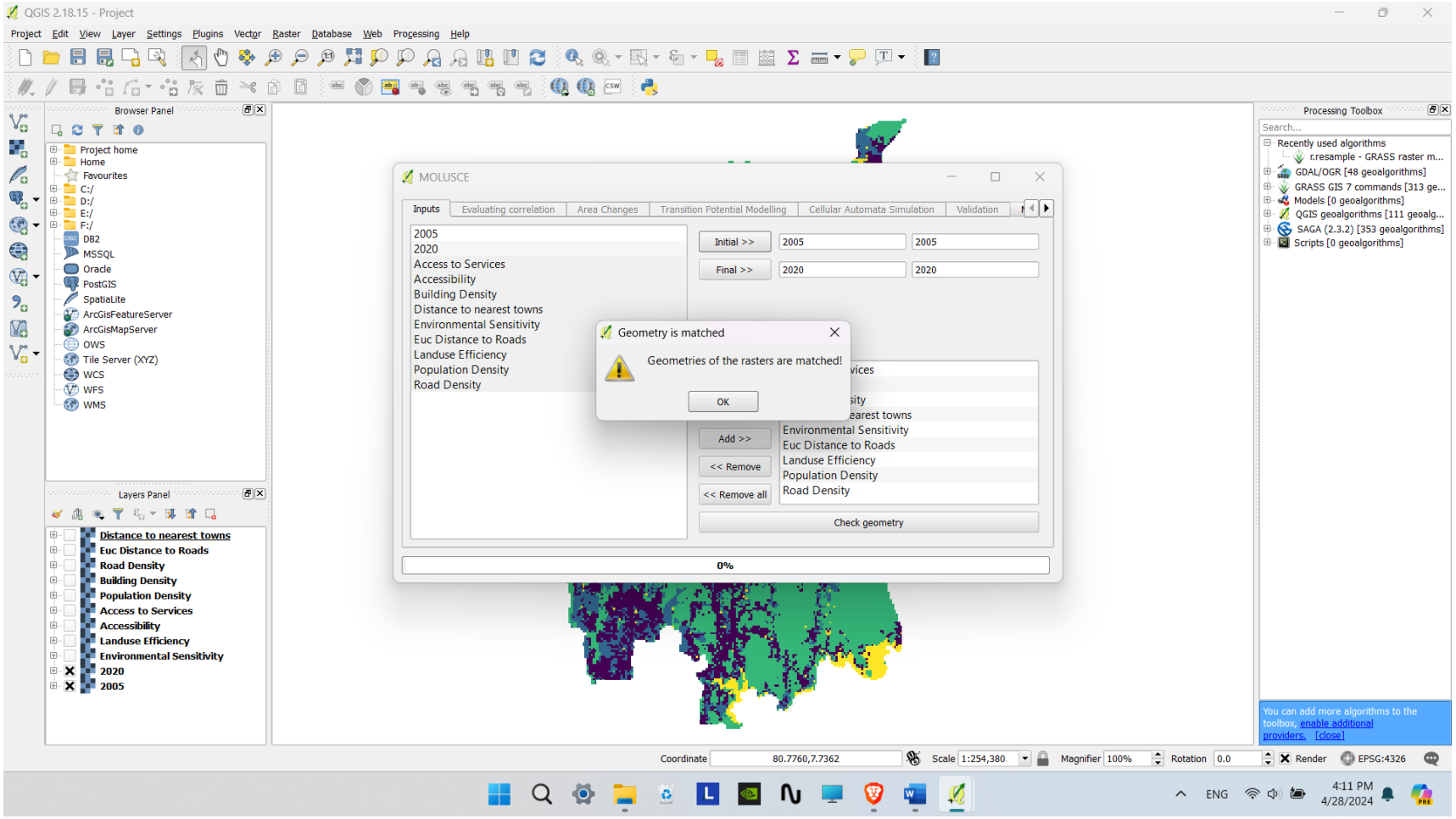
Following the same steps as before, you can add one by one layer to the model, or if you want to add these layers easily, select all spatial variables using the Ctrl key and click on "**Add**".



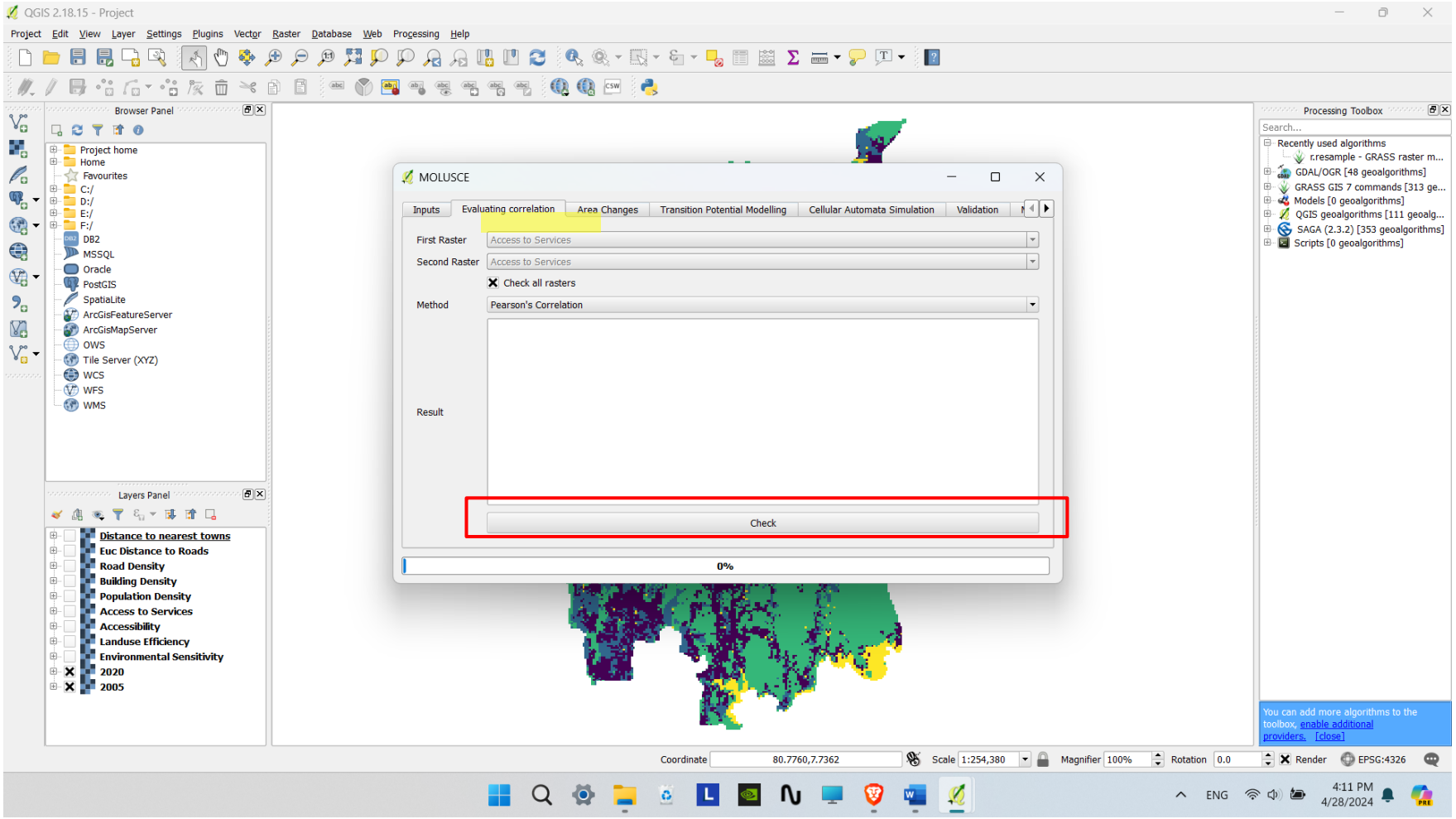
Now, all the layers are successfully added to the model.



Next, the geometries of the layers need to be checked. For that, click on "**Check geometry**". If the geometries of the all rasters are matched, the below message will be displayed. If the geometries of all the layers are not the same, the next step cannot be taken and an error message will be shown. Then the coordinate reference systems, rows and columns values, and cell sizes of all layers have to be rechecked.



Then, go to the “**Evaluation correlation**” tab. Here, Pearson's Correlation is used as the method. Now click on “**Check**” to proceed and you will get the matrix within a few seconds.



This matrix of correlation coefficients helps to understand how each spatial variable correlates with the actual changes in land use over time. By examining these correlations, we can identify which spatial factors have the strongest influence on land use dynamics and which may have a weaker or negligible impact.

This information is crucial for refining the predictive models within MOLUSCE, as it allows us to prioritize the inclusion of spatial variables based on their significance in driving land use changes. This helps to improve the accuracy and effectiveness of the predictive models by better aligning them with the real-world relationships between spatial variables and land use dynamics.

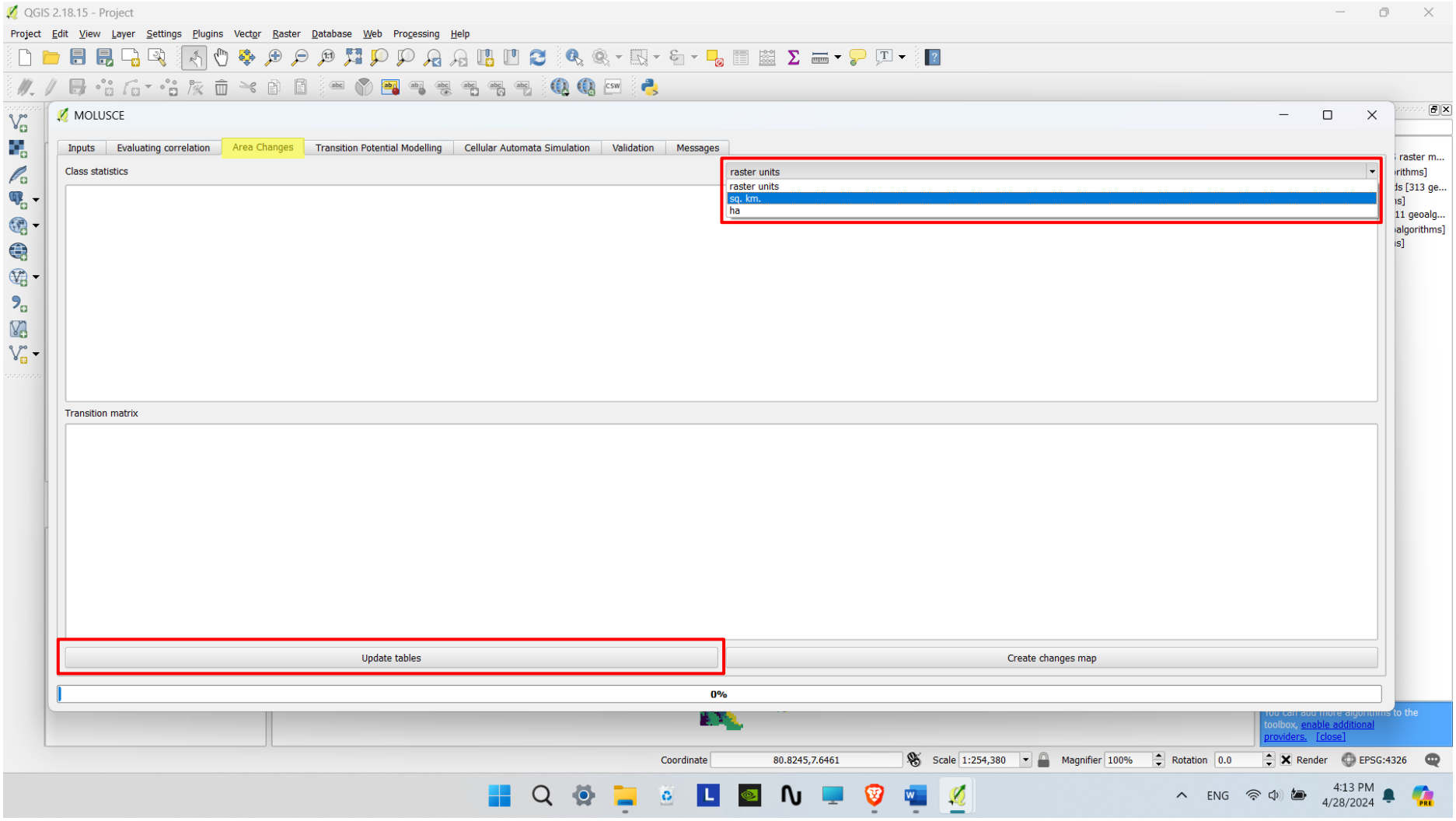
In the context of Pearson's correlation coefficient, a value of 1 indicates a perfect positive linear relationship between the two variables being compared. This means that as one variable increases, the other variable also increases proportionally. In the evaluation correlation tab of the MOLUSCE plugin, if a correlation coefficient is close to 1, it suggests a strong positive correlation between the spatial variable and the observed land use changes.

Values close to -1 or 1 indicate strong correlations, while values closer to 0 suggest weaker correlations. The sign of the correlation coefficient (+/-) indicates the direction of the relationship (positive or negative). Therefore, a correlation coefficient of 1 signifies a strong positive relationship, which is generally considered desirable in predictive modeling.

	Distance to nearest towns	Euc Distance to Roads	Building Density	Environmental Sensitivity	Accessibility	Road Density	Landuse Efficiency	Population Density	Access to Services
Distance to nearest towns	--	0.441323747095	-0.302824745992	0.176073171396	-0.516767970204	-0.419141156885	-0.368553097348	-0.365087737185	0.494748188145
Euc Distance to Roads		--	-0.367526722507	0.352616575335	-0.242689903437	-0.36763013485	-0.374035378235	-0.453683300652	0.465530602022
Building Density			--	-0.478106979998	0.529866692586	0.6872115136	0.62881778748	0.642996464628	-0.334377799996
Environmental Sensitivity				--	-0.262011864781	-0.366355019016	-0.354590823079	-0.443780849636	0.189004460298
Accessibility					--	0.576923946527	0.513134186465	0.29596831616	-0.316026309295
Road Density						--	0.572695074381	0.417413174729	-0.36235275017
Landuse Efficiency							--	0.40414335433	-0.442368556311
Population Density								--	-0.27707102474
Access to Services									--

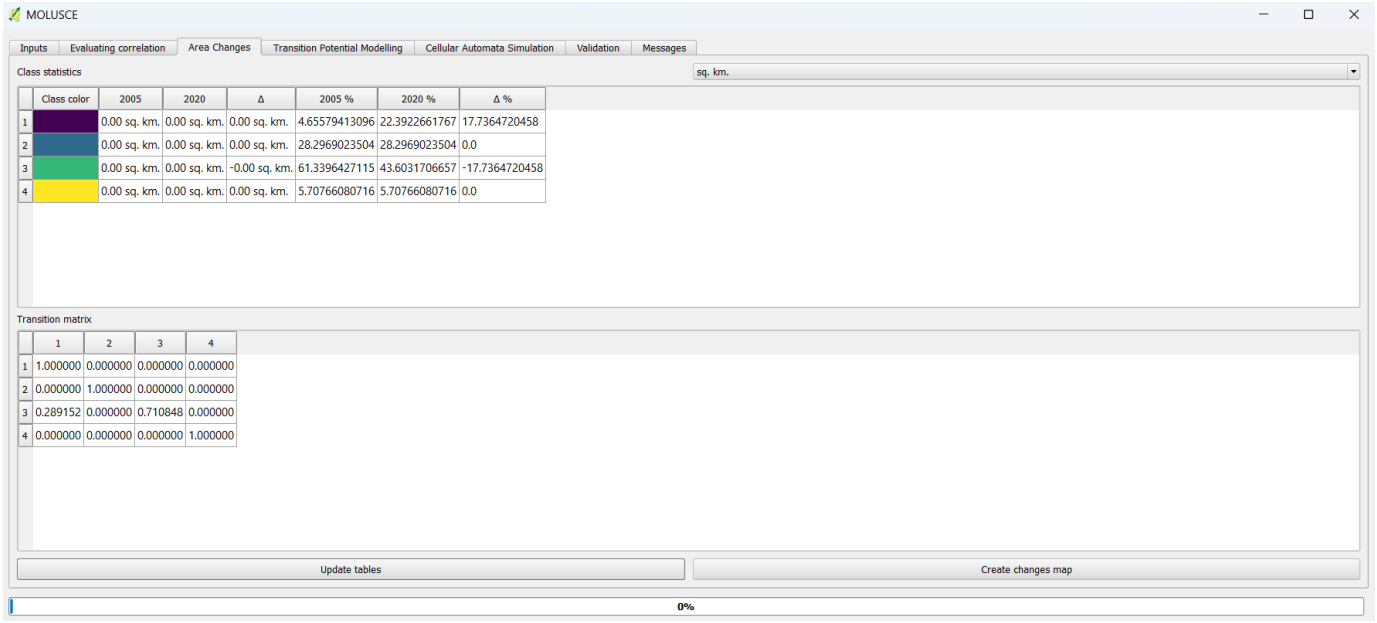
When studying this matrix, we can see that the correlation between some variables takes negative values. That is, it can be recognized that those factors may have a weak or negligible effect on land use dynamics in the Dambulla area.

Next, go to the tab “**Area Changes**”. Set the units as “**sq. km**.” as follows. Then click on “**Update tables**”.

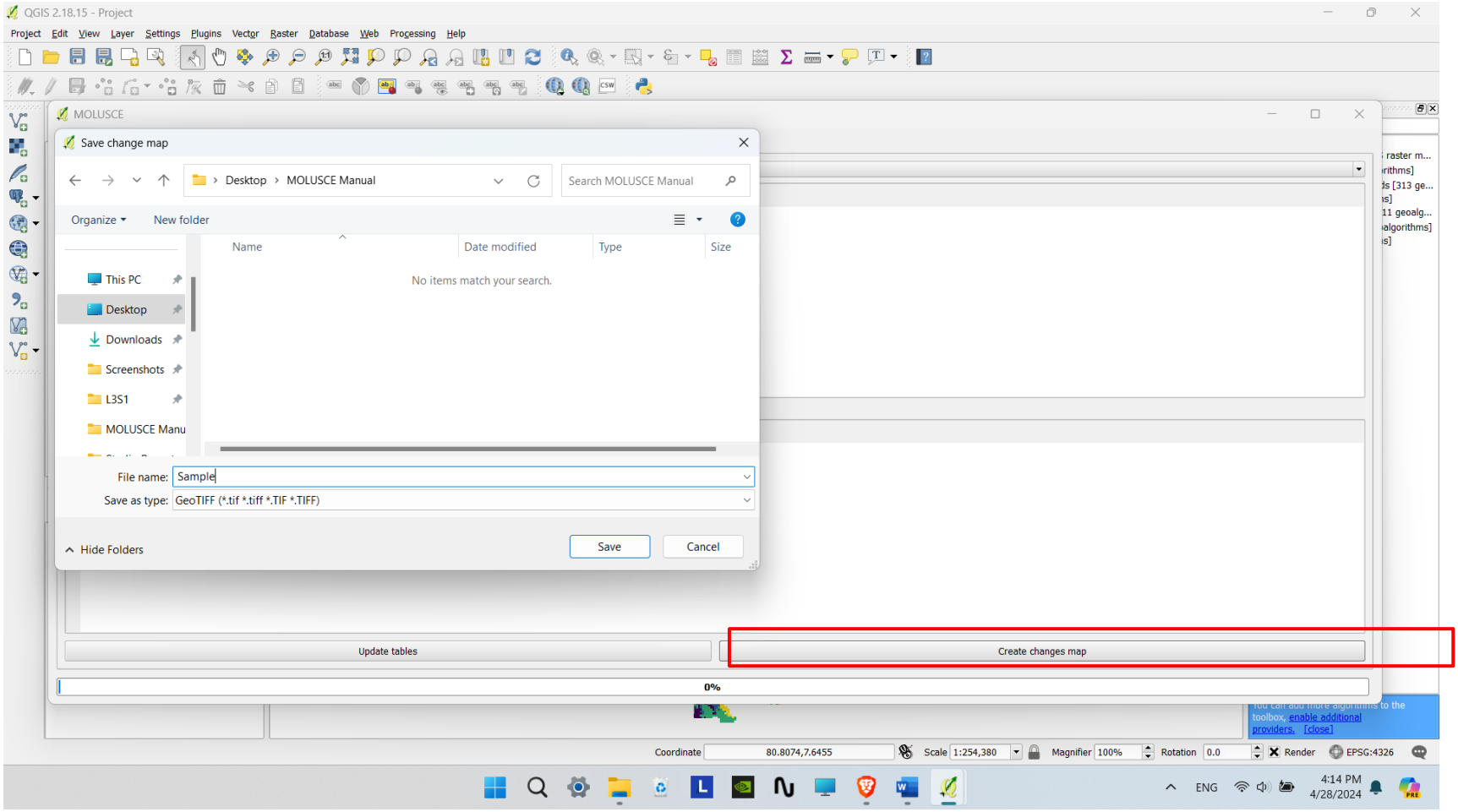


Then you will get this table and the matrix. The plugin calculates the area covered by each land use category in both time periods and then determines the changes that have occurred, such as expansion, contraction, or stability of each land use type. The purpose of this functionality is to provide us with quantitative insights into how land use has evolved or shifted over time within a specific region or area of interest. By quantifying the changes in land use, users can identify trends and patterns of land use dynamics. This information is invaluable for understanding and assessing the impacts of human activities or environmental factors, and informing land management and planning decisions.

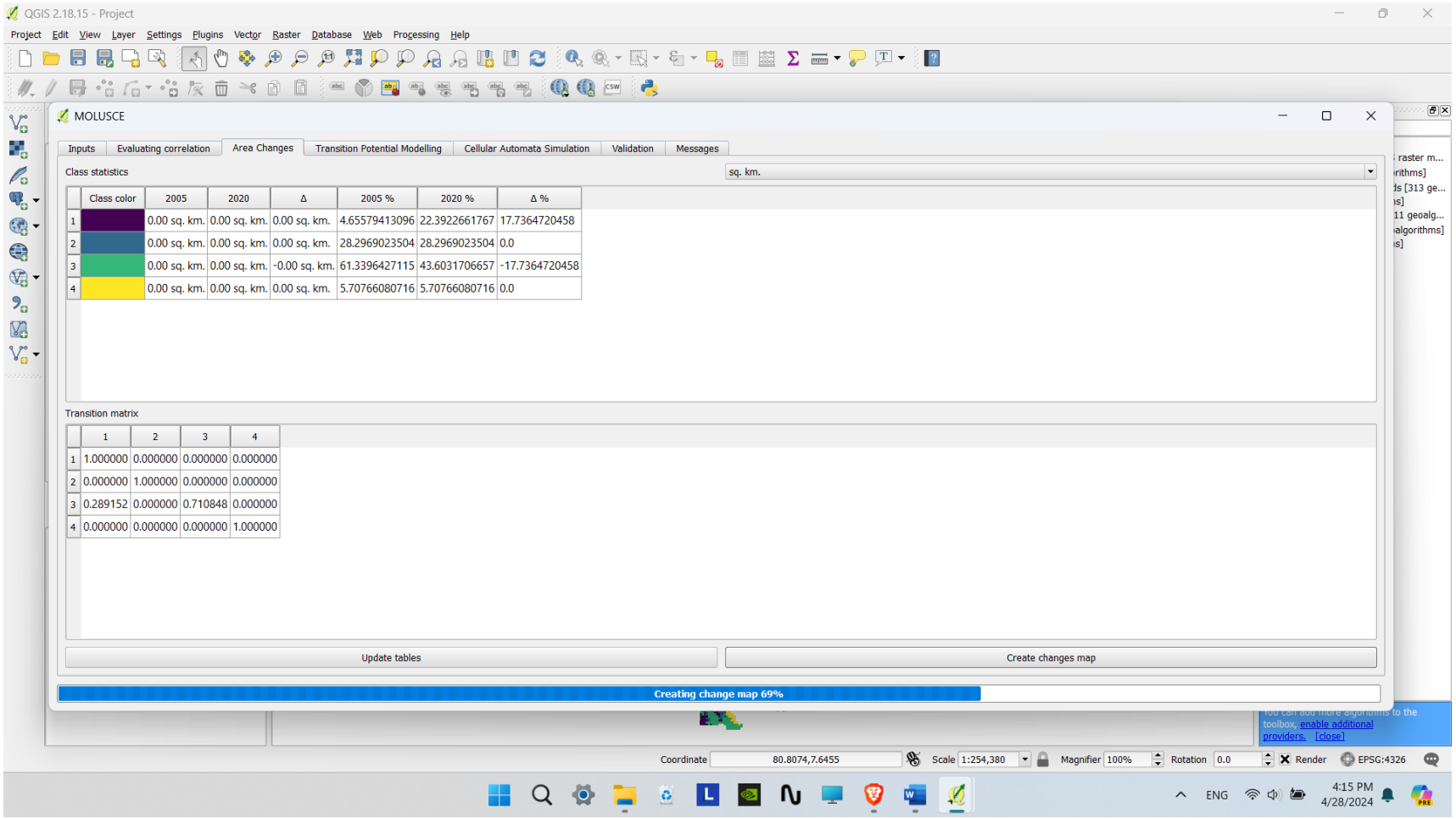
The numbers 1, 2, 3, and 4 in the class statistics table and the transition matrix indicate the four land use categories that we have selected. In this class statistics table under the "Area Changes" tab, the area change can be 0. This would indicate that the particular land use class has not experienced any change in the area between the initial and final periods being analyzed. The transition matrix shows how much area has transitioned from one land use class to another between the initial and final time periods. Each cell in the matrix represents the amount of area that has changed from one specific class to another.



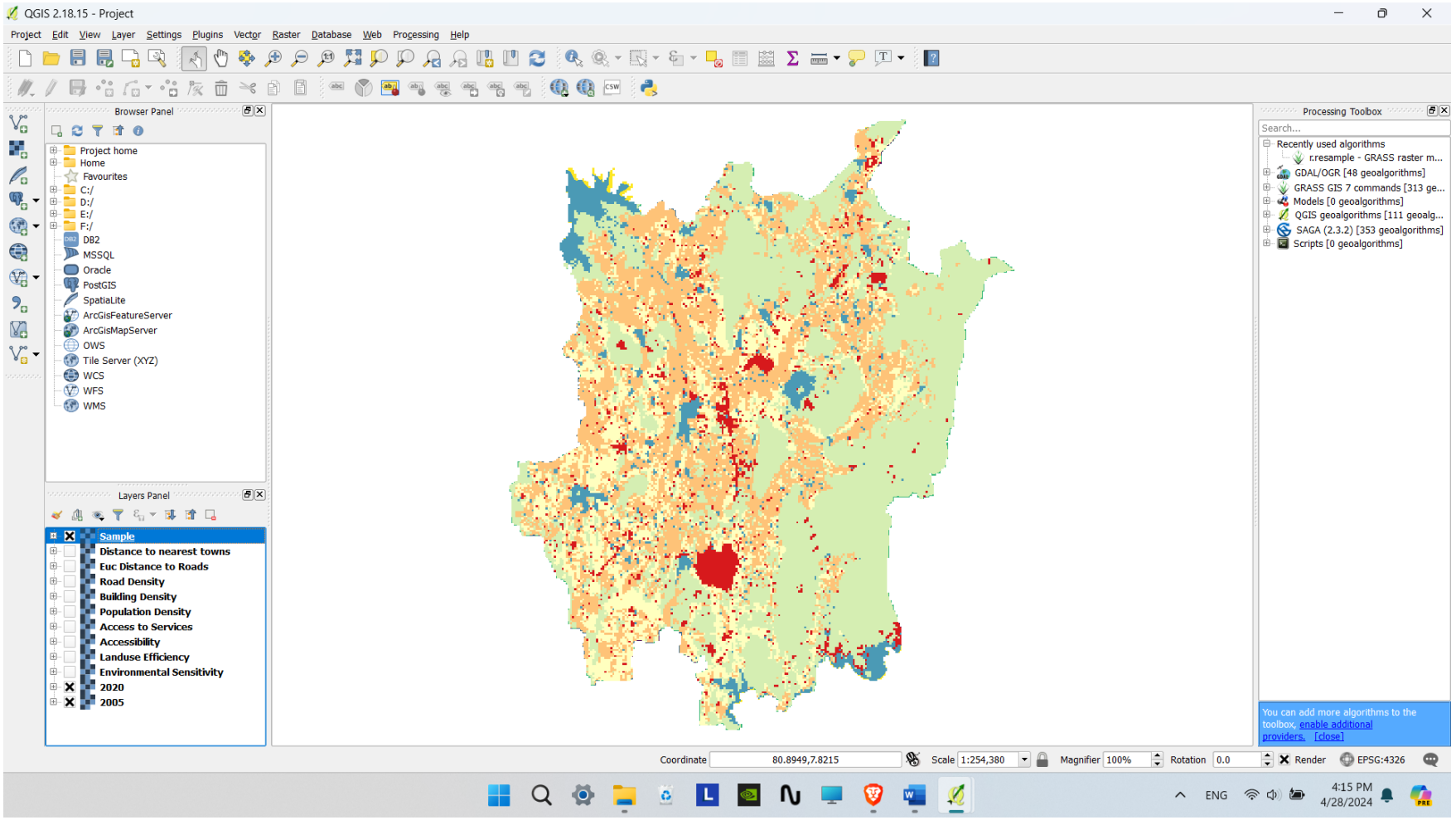
Additionally, the "**Area Changes**" tab allows us to visualize these changes through a map, enhancing the interpretation and communication of the results. For that, click on "**Create changes map**" and select a location to save the map as your preference.



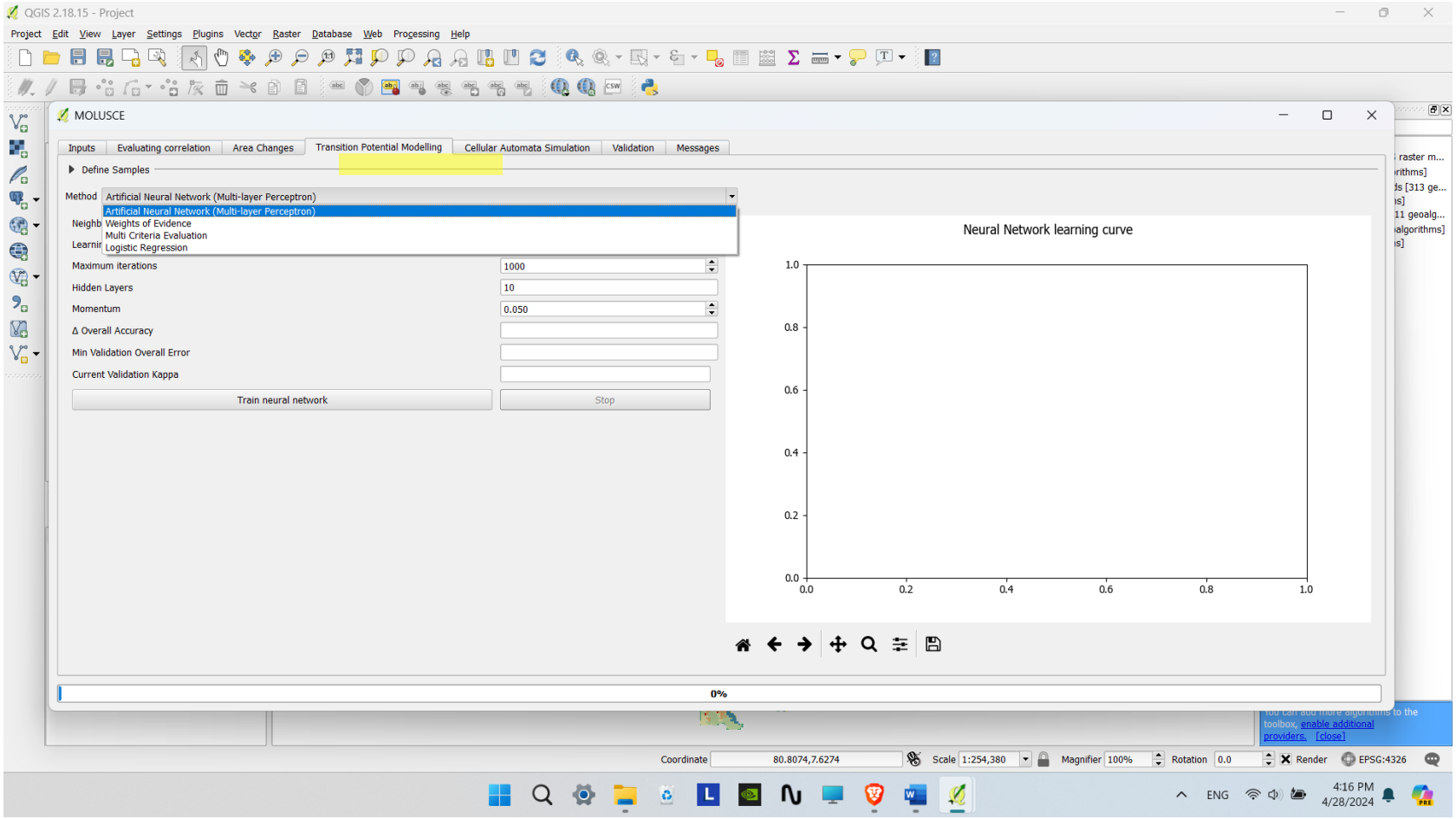
After clicking on “**Save**” in the previous step, the process will run as the below image.



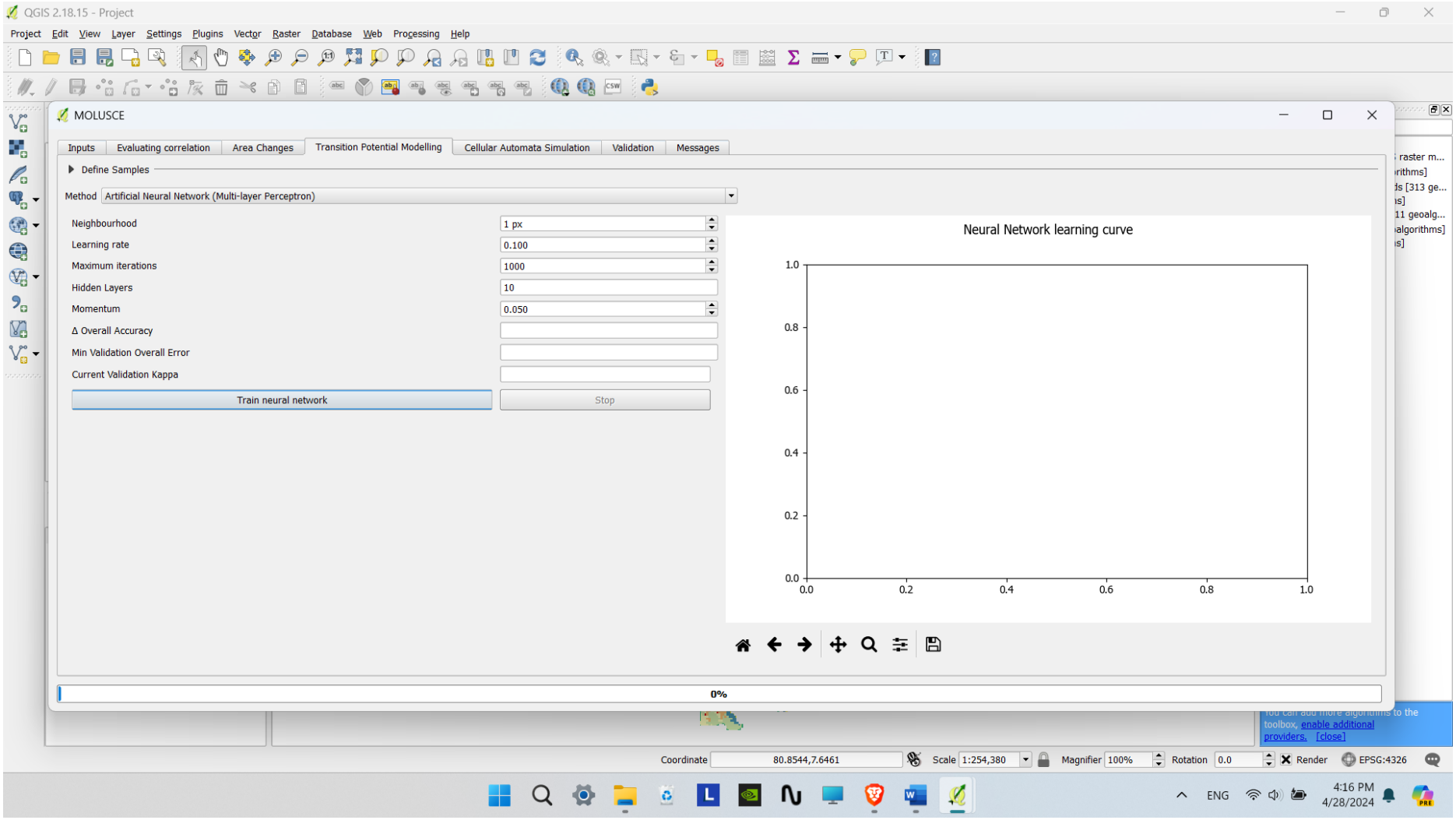
After the saving, the area change map will appear on the workspace as follows.



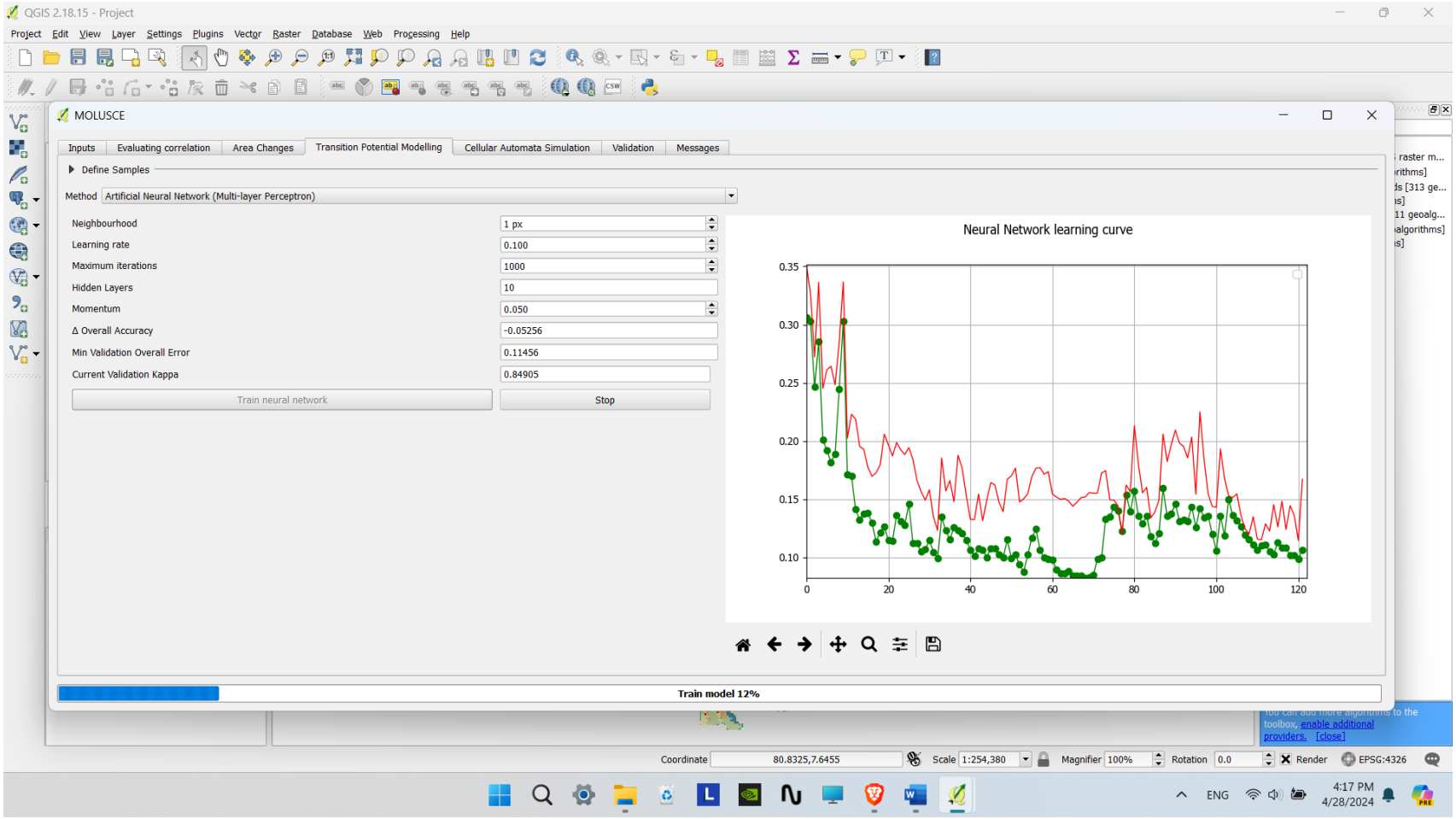
As the next step, go to the tab "**Transition Potential Modeling**" tab. Usually, we use here the **Artificial Neural Network (Multi-layer Perceptron)** as the method. Other parameters can be used as default values.


QGIS 2.18.15 - Project
Project Edit View Layer Settings Plugins Vector Raster Database Web Processing Help
MOLUSCE
Inputs
Evaluating correlation
Area Changes
Transition Potential Modelling
Cellular Automata Simulation
Validation
Messages
Define Samples
Method
Artificial Neural Network (Multi-layer Perceptron)
Weights of Evidence
Multi Criteria Evaluation
Logistic Regression
Maximum iterations
1000
Hidden Layers
10
Momentum
0.050
Δ Overall Accuracy
Min Validation Overall Error
Current Validation Kappa
Train neural network
Stop
Neural Network learning curve
0%
Coordinate
80.8074,7.6274
Scale
1:254,380
Magnifier
100%
Rotation
0.0
Render
EPSG:4326
ENG
4:16 PM
4/28/2024

Then, click on “**Train neural network**”.

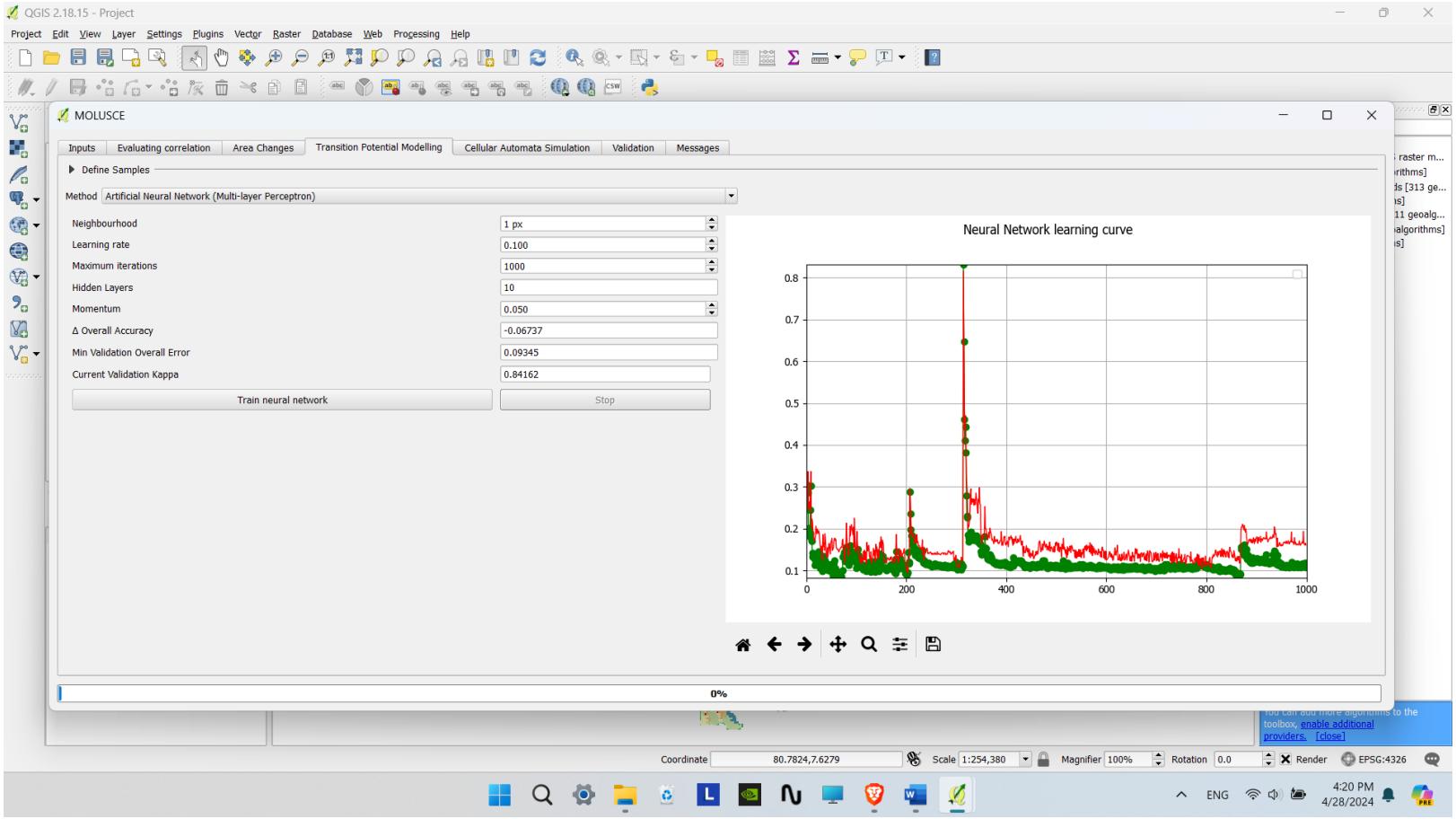


Now the model starts to train as follows. This will take a few minutes. This time depends on the speed of your internet connection and the processing speed of the computer used.



Under this part, utilizing the Artificial Neural Network (ANN), specifically the Multi-layer Perceptron (MLP) method, involves a structured process. Firstly, we selected spatial variables influencing land use change. Then, raster data representing these variables for past and present periods are inputted. The plugin

trains the MLP model using this data, calibrating it to estimate the likelihood of transitions between different land cover types. Subsequently, MOLUSCE generates transition potential maps, delineating areas with heightened probabilities of specific land use changes.



The **neural network learning curve** represents the performance of an artificial neural network (ANN) during training. It typically shows the training loss (also known as the error or cost) on the **y-axis** and the number of training iterations or epochs on the **x-axis**. The training loss measures how well the ANN is fitting the training data, and observing this curve helps determine if the model is overfitting or underfitting. As the number of iterations increases, the training loss

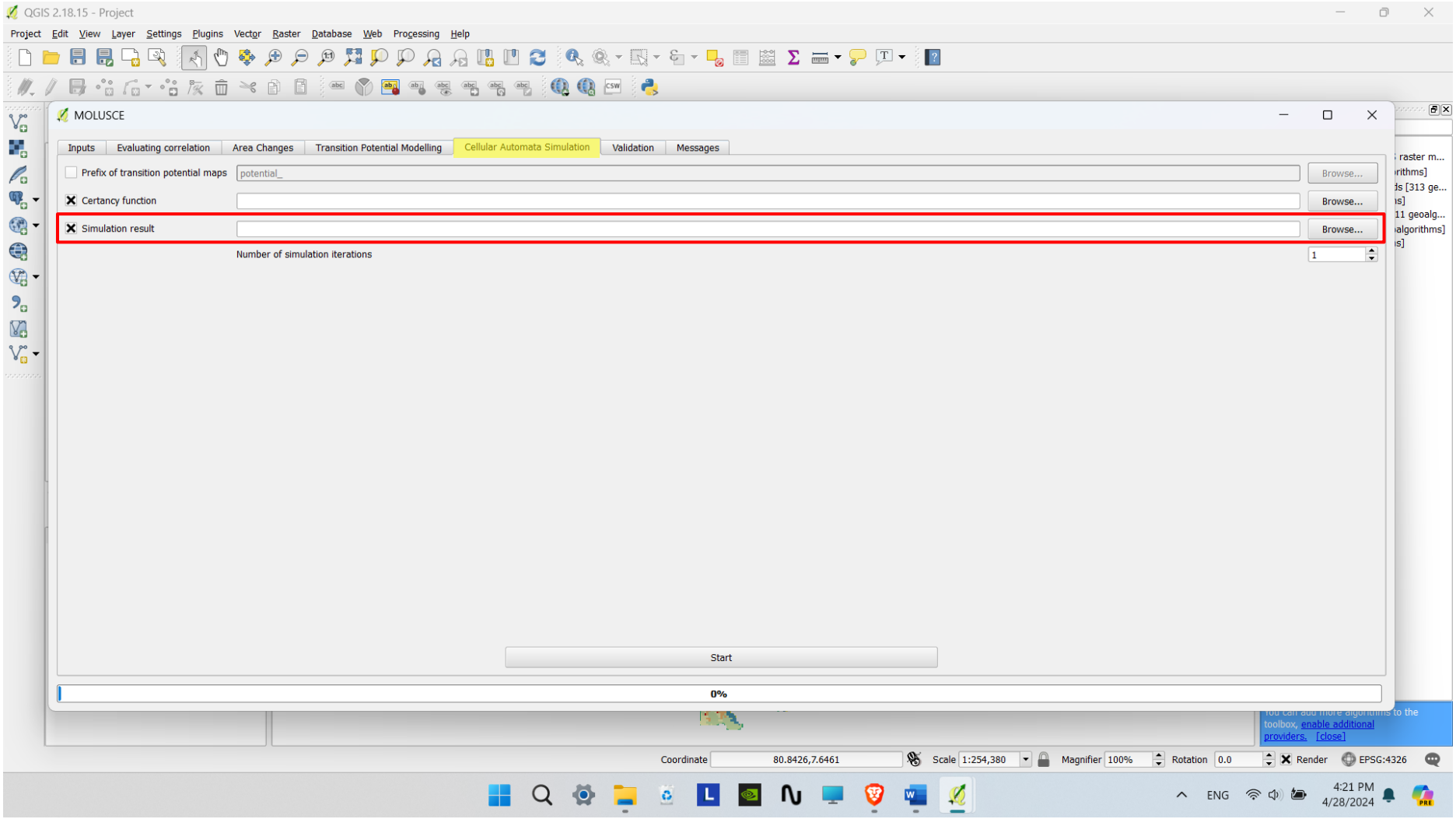
ideally decreases, indicating improved model performance. Keep in mind that specific implementations may vary, but this general trend holds for most neural network training processes.

The validation of kappa involves assessing the accuracy and reliability of the predictive models generated by comparing the predicted land use changes with observed changes here. Kappa statistics measure the agreement between the predicted and observed land use transitions, providing a quantitative measure of model performance. **Higher kappa values indicate better agreement between the predicted and observed land use changes, implying greater accuracy and reliability of the predictive models.**

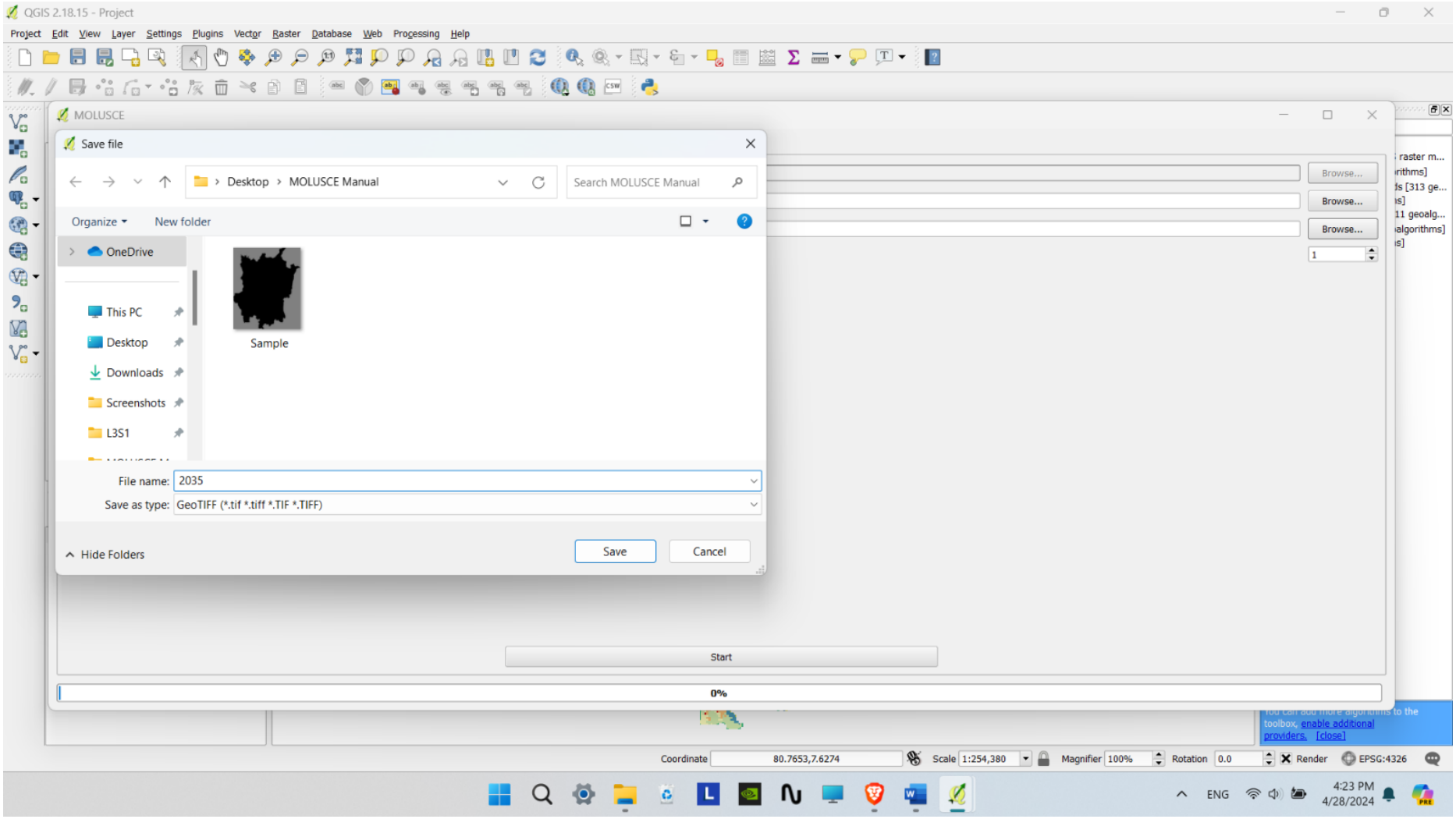
"Delta overall accuracy" refers to the change in overall accuracy between two time periods. Overall accuracy is a measure of how accurately a predictive model or classification algorithm classifies land use categories compared to ground truth data. It represents the proportion of correctly classified pixels or areas out of the total number of pixels or areas.

The "delta overall accuracy" specifically measures the difference in overall accuracy between two time periods, typically past and present. This metric provides insights into how the accuracy of land use change predictions has changed over time. **A positive delta in overall accuracy indicates an improvement in accuracy, suggesting that the predictive model is better at capturing land use changes in the present period compared to the past. Conversely, a negative delta in overall accuracy indicates a decrease in accuracy, implying that the model's predictive performance has deteriorated over time.**

Then, go to the tab “**Cellular Automata Simulation**” tab. In this step, we have to browse a suitable location to save the simulation results.

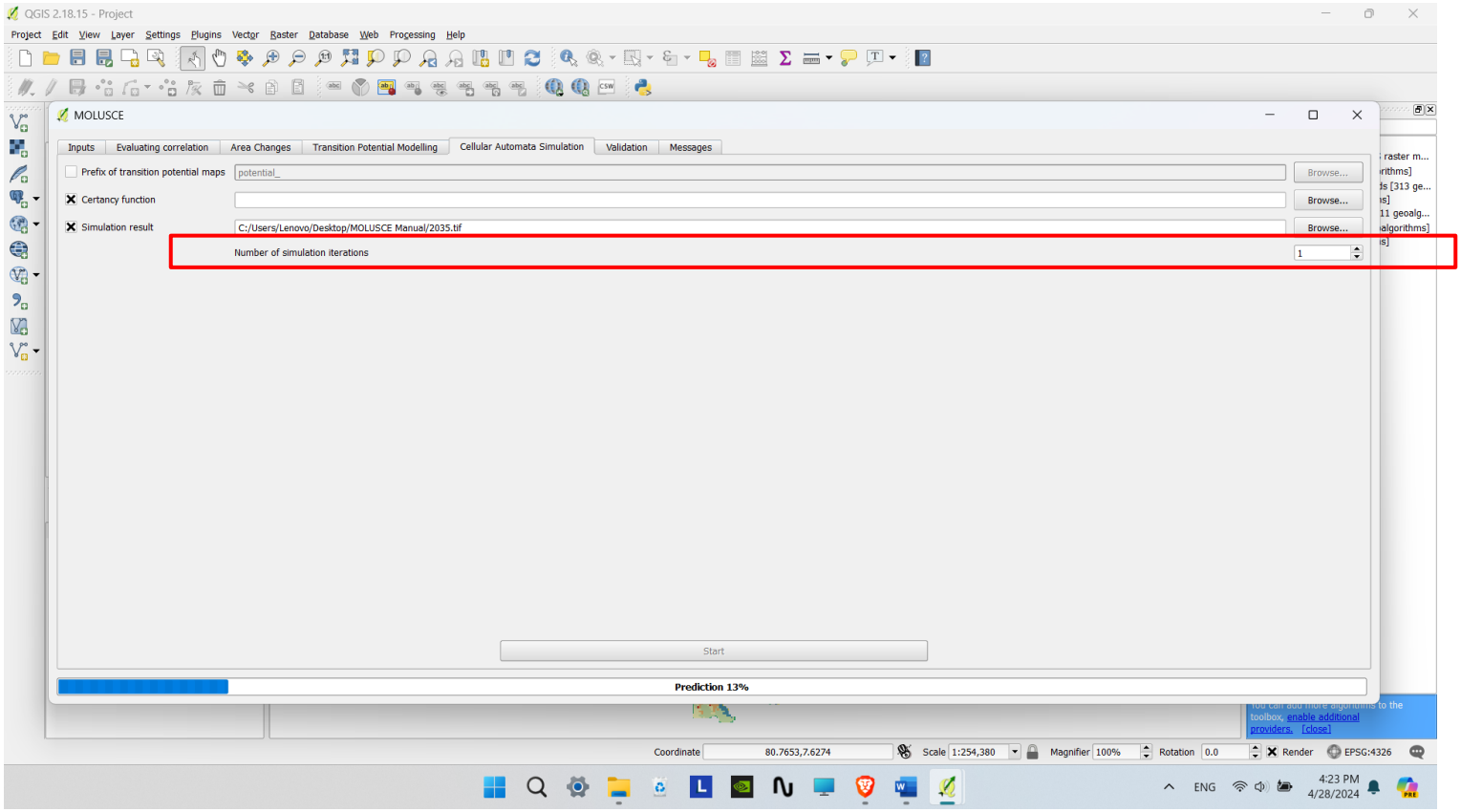


Click on “**Browse**” and select a location as follows. Then, click on “**Save**”.

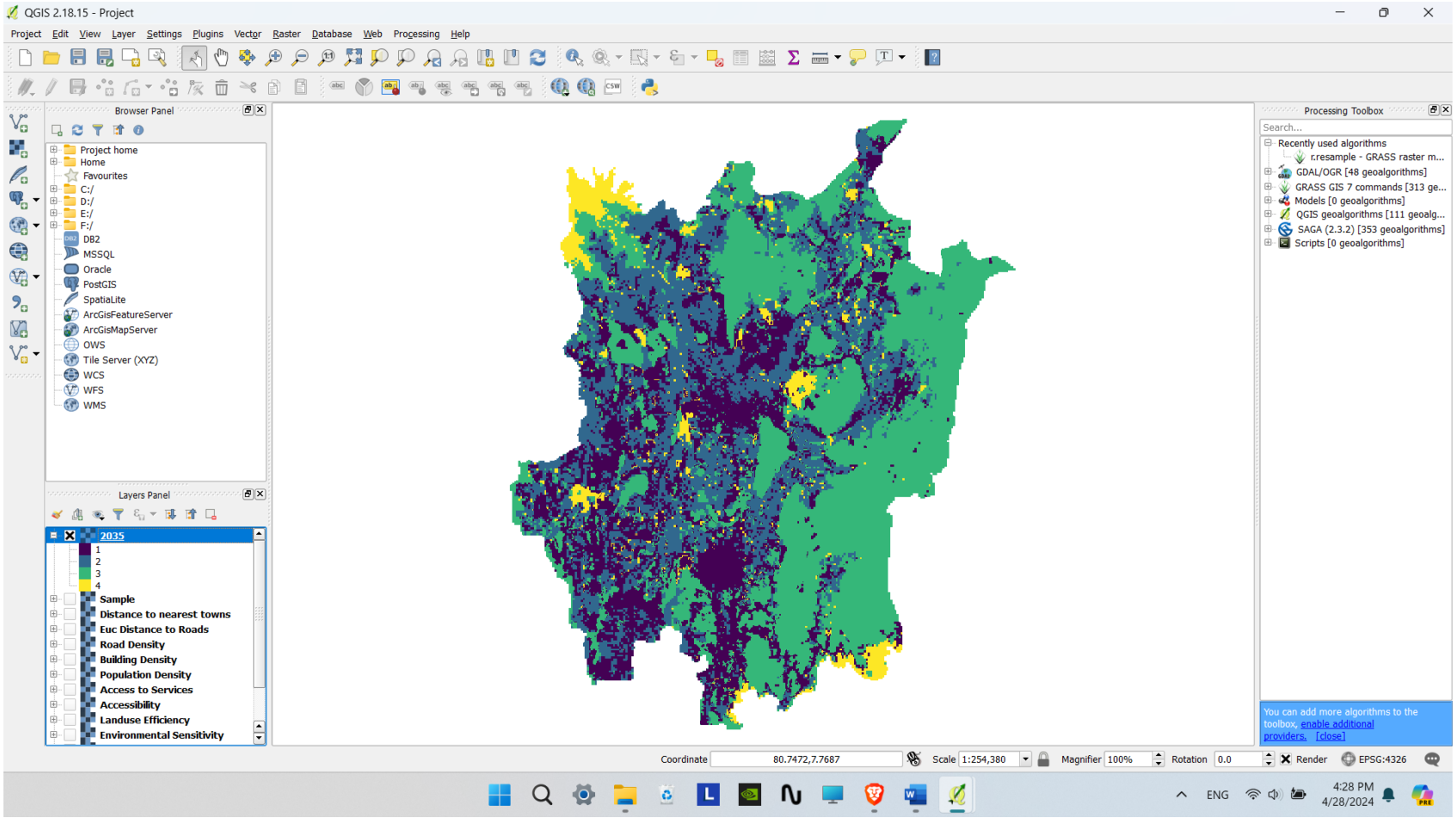

QGIS 2.18.15 - Project
Project Edit View Layer Settings Plugins Vector Raster Database Web Processing Help
MOLUSCE
Save file
Desktop › MOLUSCE Manual
Search MOLUSCE Manual
Organize
New folder
OneDrive
This PC
Desktop
Downloads
Screenshots
L3S1
Sample
File name: 2035
Save as type: GeoTIFF (*.tif *.tiff *.TIF *.TIFF)
Hide Folders
Save
Cancel
Browse...
Browse...
Browse...
Start
0%
Coordinate 80.7653,7.6274
Scale 1:254,380
Magnifier 100%
Rotation 0.0
Render
EPSG:4326
ENG
4:23 PM
4/28/2024

Then we have to set the number of simulation iterations. We used here the land use layers for the years 2005 and 2020. The gap is 15 years. So, one iteration equals 15 years here. If we set the number of iterations as "**1**" here, the prediction will be given for the year 2035. If it is set as "**2**", the prediction will be given for the year 2050.

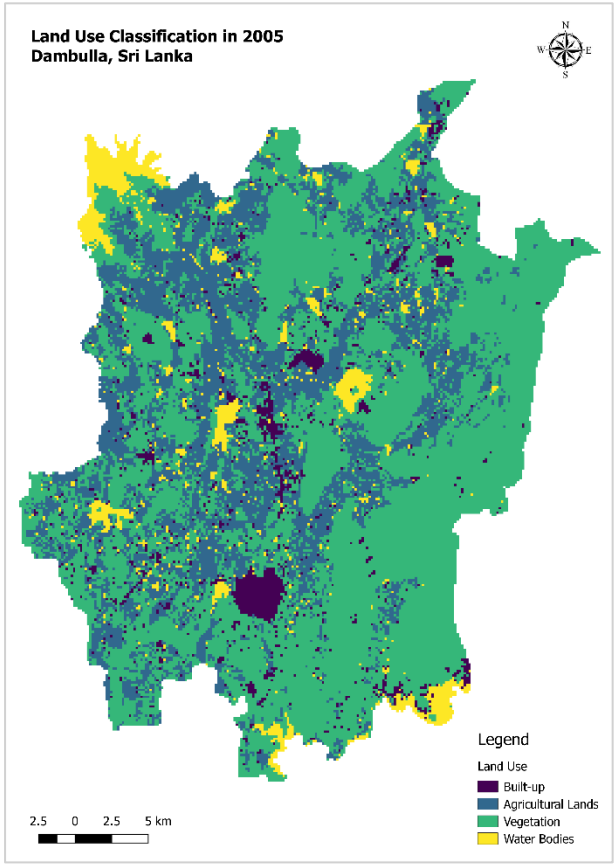
After setting up the number of iterations as above, click on "**Start**". Then the prediction will be started and it will be saved in the location that you selected before.

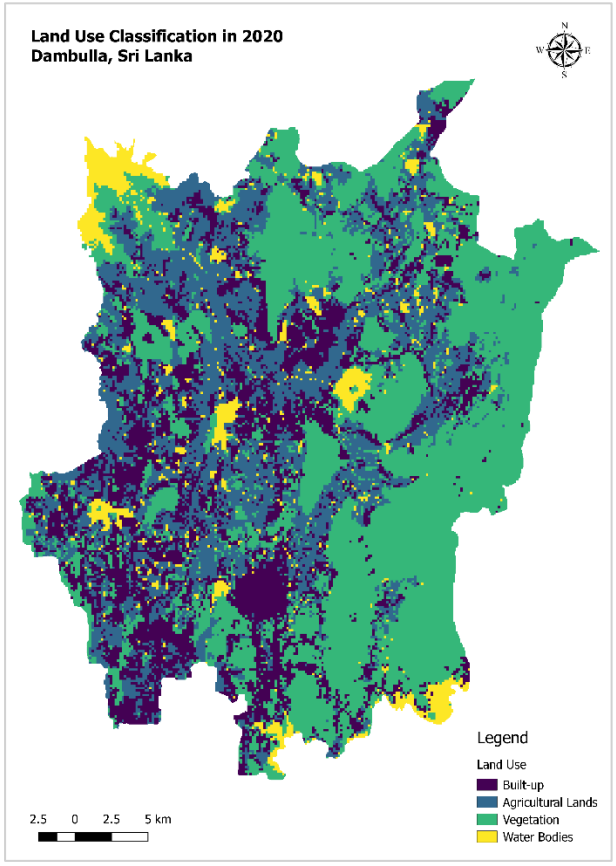


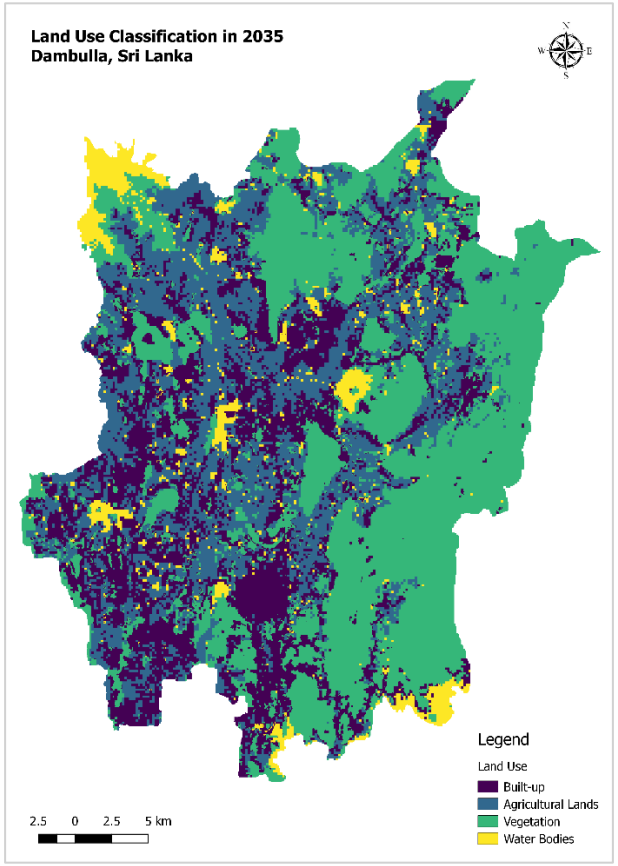
Once the prediction is done, that layer will appear on the workspace as follows. In this scenario, the number of iterations was set as "**1**", so this prediction is for the year **2035**. When you compare the 2005, 2020, and 2035 layers, you can see the land use change among those.



3.2 Past, present, and future scenarios of land use in the Dambulla region





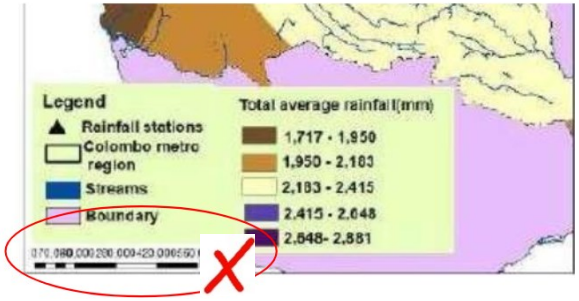


4.PREPARATION OF MAPS

1. Use Suitable Colors & Symbols
2. Show adjacent administration boundaries.
3. Maximum utilization of map space
4. Show the Graticule Network with appropriate grid size.
5. Show the basic elements in the map.
    a. Transportation Networks
    b. Water Bodies
6. Prepare a descriptive map.
    a. Label notable features.
        i. Major Road Types
        ii. Major Rivers
        iii. GN Boundaries
        iv. If needed, show the location of the area in a different data frame.
7. Check the units of the scale bar.
8. Mention correct units at the legend.
9. Check the text given in the legend.
10. Mention the correct sources.

Examples

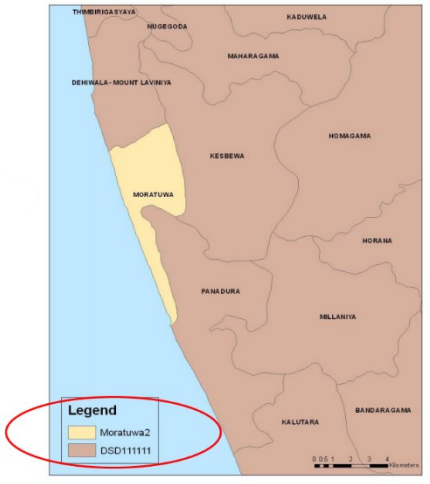
Maximum utilization of map space

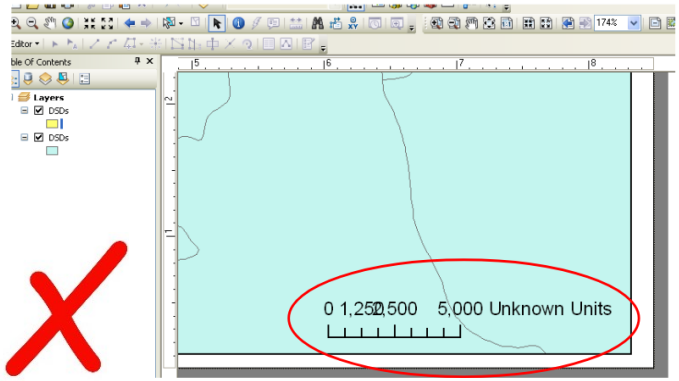


Check the units of the scale bar.

Mention the correct sources.

Figu





AFTERWORD

Effective land use planning requires more than just understanding current conditions—it demands foresight, analytical precision, and the ability to simulate change. This textbook provides a rigorous, methodologically sound framework for modeling future land use scenarios using the MOLUSCE plugin in QGIS, grounded in robust algorithms such as Artificial Neural Networks, Logistic Regression, and Weight of Evidence.

Developed with both academic and professional audiences in mind, this book bridges theory and application, enabling users to engage confidently with complex spatial dynamics. As the pressures of urbanization, environmental change, and resource management intensify, tools like these become indispensable for anticipating growth, mitigating risks, and guiding sustainable development.

We hope that this publication not only enhances technical proficiency but also fosters critical thinking and strategic planning in support of resilient, adaptive landscapes. May it serve as a lasting resource for those committed to shaping the future of land use through data-driven insight and informed decision-making

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