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A Computationally Reproducible Approach to Dijkstra's Shortest Path Algorithm

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Keywords
Shortest path,
Routing Algorithms,
Dijkstra's Algorithm,
NetworkX.

ABSTRACT

One of the common problems in spatial analysis is the Shortest Path Problem (SPP), which aims to determine the shortest path between any given two points on a network structure. Although Shortest Path Problem is a widely used in spatial analysis, there has been lack of online resources to ease learning of the method with a computationally reproducible approach. This article presents how Dijkstra's algorithm works when finding the shortest path. Specifically, the developed online tutorial relied on the openly available road network data of San Francisco, NetworkX a Python package to realize complex graph analysis, and finally QGIS to visualize the shortest paths. All of the discussed material is presented as a Jupyter Notebook to ease computational reproducibility.

1. INTRODUCTION

A graph (network) data structure is commonly used in a Geographical Information System software for various purposes ranging from navigation (Zeng & Church, 2009) to social network analysis (Kumar, Kumar, & Soni, 2021). A graph is composed of nodes and edges, where an edge links two nodes. One of the purposes that utilize graph data structures in geomatics applications is the identification of the least-cost tree connecting all nodes of a graph (i.e. identification of the minimum spanning tree). Such an approach could be used to optimize the structure of an, for example, electricity-distribution network (Çalışkan & Anbaroğlu, 2020) and path planning. Finding the shortest path between two nodes of a graph is widely used not only in our daily lives but also for designing efficient public transportation systems (Yu, Kong, Shao, & Yan, 2018).

The Shortest Path Problem (SPP) consists of determining a path between a beginning (source) location and an end (target) location, such that the distance is minimum compared to alternatives (Rout, Vemireddy, Raul, & Somayajulu, 2020). In general, SPP is represented by a graph with several paths to be evaluated, which represents a computational difficulty. Thus, many types of research from computer science and engineering areas focus on developing efficient algorithms to solve the SPP (Huber & Rust, 2016).

The wide use of SPP in research and practice necessitates the development of openly available solutions that eases learning and experimentation. Amongst the other scripting/programming languages, Python programming language is prominent due to its natural integration to QGIS, a commonly used open-source GIS software. Furthermore, the availability of Jupyter Notebook, which is a computational notebook where a researcher can integrate both code and explanatory text. Utilizing computational notebooks have recently been used in data science and teaching GIS related courses (Kim & Henke, 2021).

This research aims to develop a computationally reproducible approach to Dijkstra's algorithm, one of the first algorithms to solve the SPP, by employing one of the renowned Python packages, *NetworkX*, on an openly available dataset. The developed Jupyter Notebook, and data are shared on GitHub to ease computational reproducibility (*GitHub - Banbar/Shortest_path_Dijkstra*, n.d.).

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2. METHOD

This section first describes the Dijkstra's algorithm and then the NetworkX package.

2.1. Dijkstra's Algorithm

Dijkstra's algorithm is an algorithm for finding the shortest paths between nodes in a graph, which may represent, for example, road networks. The algorithm is it has O(nlogn) complexity. Also, this algorithm makes a tree of the shortest path from the starting node, the source, to all other nodes (points) in the graph.

Dijkstra's algorithm assumes an infinite weight to the nodes if it does not readily know their weights. Specifically, when moving from node A to node E, as illustrated in Figure 1, the algorithm initially assumes that reaching node E would have an infinite cost. This is because node E is not adjacent to node A. This is represented in the first step of the algorithm illustrated in Table 1.

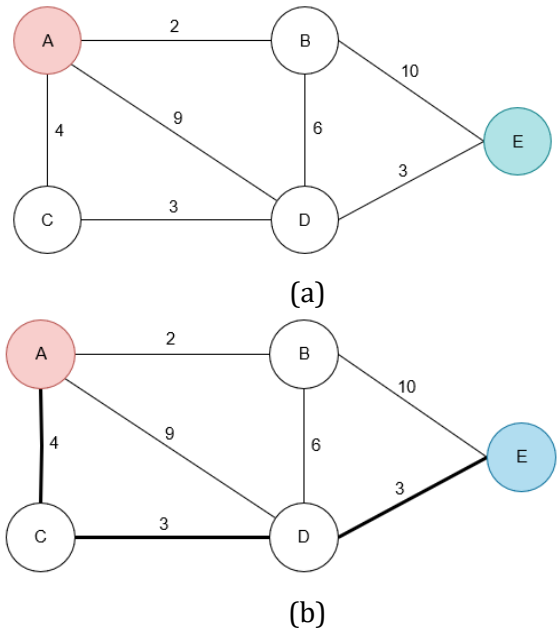

Figure 1. A sample graph (a), the shortest path between nodes A and E with a total cost of 10 (b)

We assume that the route starts at node A and finishes at node E. The execution steps are illustrated in Table 1 consisting of four steps. First step of Dijkstra's algorithm is to identify the weights of the neighbors of the start point. The weights of the neighbors of node A are illustrated in Table 1. After finding the adjacent nodes, the algorithm moves to the node that has the least cost. Specifically, in the second step the algorithm starts searching the graph from node B. Since moving to node B incurs of cost of two, it is also recorded. For example, the cost of edge BD is six, and with the additional cost of two to reaching node B, it has a weight of eight. As this is an improvement, an update operation takes place in terms of reaching node D, which used to be from node A with a weight of nine. Once all the nodes are visited, the algorithm terminates.

The resulting fourth step identifies all the shortest paths from node A. It is straightforward to determine the shortest path, from example to node E, by following the previous nodes. Starting from the target, E, its previous node is D, whose previous node is C, and whose previous node is A (i.e. E → D → C → A). Consequently, the shortest path from node A to node E is the reverse of the outcome, which is A → C → D → E. The algorithm can be generalized to directed graphs, where the cost of an edge AB may differ from BA, by keeping an adjacency list of nodes.

Table 1. Execution steps starting from node A

Step 1: Current Node A (total cost = 0)

To	Weight	Prev. Node
B	2	A
C	4	A
D	9	A
E	∞	-

Step 2: Current Node B (total cost = 2)

To	Weight	Prev. Node
B	2	A
C	4	A
D	8	B
E	12	B

Step 3: Current Node C (total cost = 4)

To	Weight	Prev. Node
B	2	A
C	4	A
D	7	C
E	12	B

Step 4: Current Node D (total cost = 7)

To	Weight	Prev. Node
B	2	A
C	4	A
D	7	C
E	10	D

The algorithm is simple and effective. In order to run Dijkstra's algorithm faster, identification of the next node to visit can be realized by storing the weight values in a *minimum heap* data structure. The min-heap property is that when you take any two nodes of the tree (let's call them X and Y) the value of node X is greater than or equal to the value of node Y if X is a child of Y. In this way, if we move from any node to the root of the tree, the value should never increase. In this way, the weights of the nodes are sorted in ascending order and a route is created by checking the ones with less weight. An exemplar minimum heap structure is provided in Figure 2.

In addition, a heap must be a complete binary tree, which allows storing the values of a heap in a linear list structure as shown in A thorough description of a min-heap is provided (Necaise, 2011). It should be noted that complex data structures such as radix heap, may increase the computational performance of finding the SPP (Ahuja, Mehlhorn, Orlin, & Tarjan, 1990).

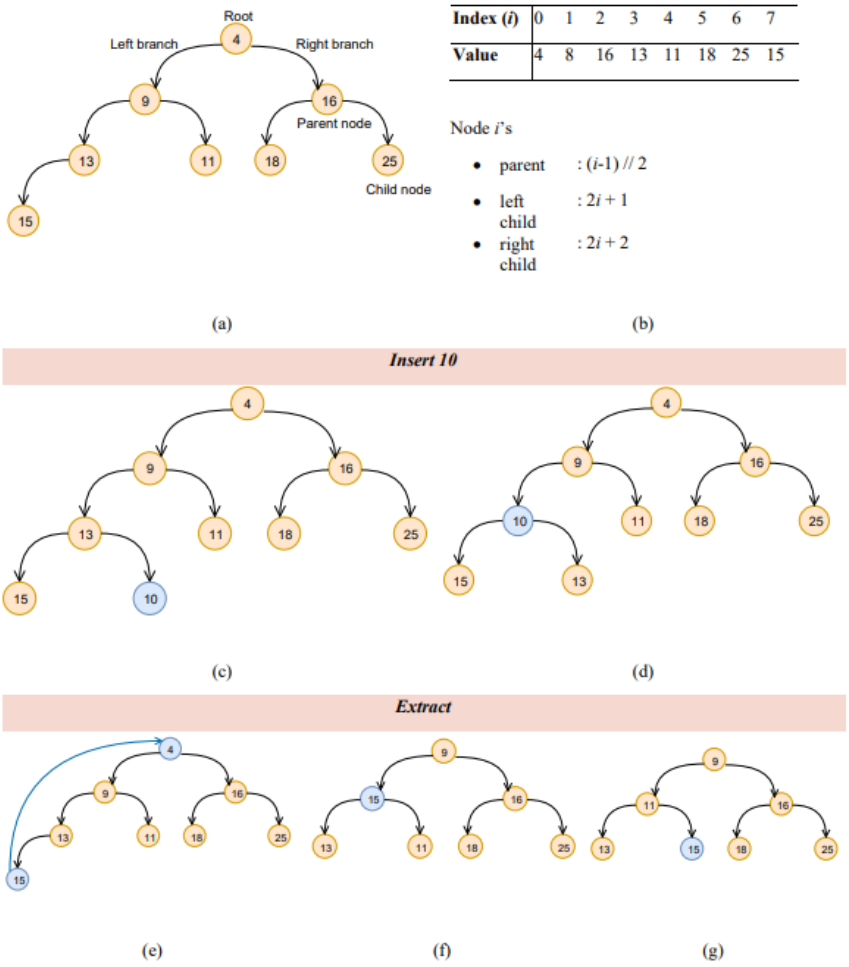

Figure 2. A min-heap (a) and its list representation (b). Inserting ten (c,d) and extraction from the heap (e, f, g)

2.2. NetworkX

NetworkX is a Python package for graph analysis. This package helps to create, manipulate, and investigate the structure, dynamics, and functions of complex networks. It is used to study large complex networks represented in form of graphs with nodes and edges. Using NetworkX, one can load and store complex networks. The potential audience for NetworkX includes mathematicians, physicists, biologists, computer scientists, and social scientists. As of 22 February 2022, 83 papers appear on SCOPUS with the keyword "NetworkX". It allows computational reproducibility as the package is free software, and can be redistributed and/or modified under the terms of the BSD License. ("Overview — NetworkX 1.10 Documentation," n.d.).

3. RESULTS

This section first describes the openly available dataset of San Francisco city. Second the execution steps of the developed Jupyter Notebook are described. The results described in this section are computationally reproducible, which is considered to ease testing on other datasets as well as experimenting on a similar process.

3.1. San Francisco Road Network

This San Francisco Road network data set is obtained from the ACM SIGSPATIAL GIS Cup 2015 competition(*ACM SIGSPATIAL GIS Cup 2015*, n.d.). The reason for choosing this data set is that it is open data source. This road network dataset contains routes and nodes. Each row of the file *sfo_roads.txt* represents an edge and edges are one-way edges. If an edge represents a two-way street, edges are unsigned or with negative sign. For example: 123456, -123456.

Table 2. Properties of the San Francisco Road Data set

Characteristic	Result
Total Length of Roads	9743 (km)
Total Number of Nodes	42408
Total Number of Roads	96850

It should be noted that, there are islands in this dataset. Specifically, some nodes do not have access to other nodes because the start and end points of some paths are written incorrectly. The Figure 3 is serves as a good example of this.

Figure 3. Islands in the data set (Example node id: 48526416)

3.2. Finding the Shortest Path

In order to find the shortest path with the NetworkX package, the following Python packages need to be installed. First, as the road network data is originally recorded as a shapefile (.shp), it must be opened and stored for processing in Python. For this purpose, *GeoPandas* package is used. Second, in order to record the execution time of the whole process, the *time* package is used. Finally, to experiment on random start and end locations, the *random* package is used.

In order to use the "*shortest_path*" function of NetworkX, an array with three elements must be designed: i) the start point, ii) end point, and iii) the weight, which is the cost between the start and end nodes (points). In this paper's context, the weight value is the distance between two points.

At this point, the *shortest_path* function can be executed. If there are routes between these two points, the algorithm will select the least cost path. On the other hand, if there is not a route between the randomly selected two points, it will return "No path between 'Start Point ID' and 'End Point ID'". These steps are summarized in Figure 4.

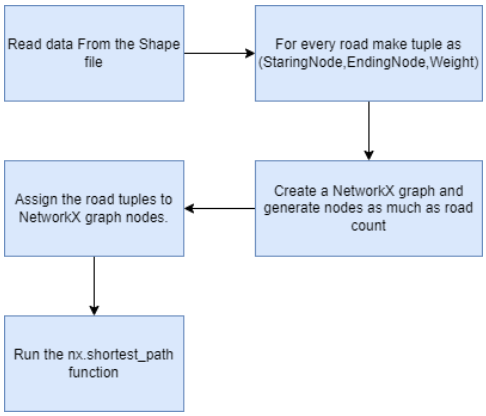

Figure 4. Methodology of using NetworkX shortest_path function with a shapefile.

The developed Jupyter Notebook handled the scenario where the start or end point is located in another island, as illustrated in Figure 3. Specifically, the developed function Random_Dijkstra_NetworkX() runs as intended as shown in Figure 5.

```
Random_Dijkstra_NetworkX()
```

```
' "ID" = 48523524 or  "ID" = 48523666 or  "ID" = 48523669 or  "ID" = 48523679 or  "ID" = 48523682 or  "ID" = 48523691 or  "I
= 48523683 or  "ID" = 48523718 or  "ID" = 48523726 or  "ID" = 48523729 or  "ID" = 48524359 or  "ID" = 48524360 or  "ID" = 48
379 or  "ID" = 312289200 or  "ID" = 312289201 or  "ID" = 48524378 or  "ID" = 811331450 or  "ID" = 863219895 or  "ID" = 96832
8 or  "ID" = 48524445 or  "ID" = 863189477 or  "ID" = 48524451 or  "ID" = 48524450 or  "ID" = 48524448 or  "ID" = 48524449 o
"ID" = 48524686 or  "ID" = 863188342 or  "ID" = 48524668 or  "ID" = 48524666 or  "ID" = 48524667 or  "ID" = 812154015 or  "I
= 48524676 or  "ID" = 48524680 or  "ID" = 48524723 or  "ID" = 312337972 or  "ID" = 48524726 or  "ID" = 48524721 or  "ID" = 4
4722 or  "ID" = 48524737 or  "ID" = 48524736 or  "ID" = 48524738 or  "ID" = 48524739 or  "ID" = 48524651 or  "ID" = 48530532
"ID" = 48530533 or  "ID" = 48530531 or  "ID" = 48530535 or  "ID" = 48530550 or  "ID" = 946460163 or  "ID" = 946460162 or  "I
= 947213705 or  "ID" = 48530547 or  "ID" = 48530556 or  "ID" = 816720638 or  "ID" = 886118424 or  "ID" = 850784614 or  "ID"
68054914 or  "ID" = 48530609 or  "ID" = 847345328 or  "ID" = 847345327 or  "ID" = 855080308 or  "ID" = 48530601 or  "ID" = 8
80309 or  "ID" = 276604275 or  "ID" = 968081241 or  "ID" = 48530628 or  "ID" = 968081242 or  "ID" = 816720639 or  "ID" = 294
512 or  "ID" = 968058482 or  "ID" = 48530664 or  "ID" = 48530669 or  "ID" = 816720715 or  "ID" = 872523076 or  "ID" = 872483
or  "ID" = 849382730 or  "ID" = 816720703 or  "ID" = 816720702 or  "ID" = 48530582 or  "ID" = 968053457 or  "ID" = 48530784
"ID" = 48530797 or  "ID" = 801727302 or  "ID" = 48530832 or  "ID" = 872566158 or  "ID" = 816720654 or  "ID" = 816720653 or
D" = 816720652 or  "ID" = 816720655 or  "ID" = 48531078 or  "ID" = 855119728 or  "ID" = 816720700 or  "ID" = 48531125 or  "I
= 19700537 or  "ID" = 816720698 or  "ID" = 872567356 or  "ID" = 19693746 or  "ID" = 872617564 or  "ID" = 967917458 or  "ID"
8531213 or  "ID" = 872576242 or  "ID" = 48532194 or  "ID" = 847346966 or  "ID" = 967913440 or  "ID" = 108479651 or  "ID" = 4
2221 or  "ID" = 953614894 or  "ID" = 48532418 or  "ID" = 962946926 or  "ID" = 48532426 or  "ID" = 974874185 or  "ID" = 48532
or  "ID" = 48532452 or  "ID" = 48532455 or  "ID" = 94350501 or  "ID" = 872644900 or  "ID" = 872662117 or  "ID" = 48532635 or
"ID" = 970042383 or  "ID" = 48532637 or  "ID" = 961641072 or  "ID" = 968262403 or  "ID" = 968262402'
```

(a)

```
Random_Dijkstra_NetworkX()
```

```
'There is no path between 48527259 and 48525579.'
```

(b)

Figure 5. An exemplar shortest path computation with an SQL output (a), failed execution (b)

In Figure 5, a route exists between the randomly generated start and end nodes. The function the function returns then return the SQL code to select the nodes that can be directly executed in QGIS for selection. On the other hand, there might not be a route between the randomly selected points, which is also handled as shown in Figure 5b. Further explanation is also provided to highlight which nodes are in different islands.

4. DISCUSSION

Although the details regarding a single randomly generated could be obtained, a more comprehensive experimental setup was required in order to have a better understanding on the distribution of run -times. Therefore, the last cell of the developed computational notebook allows a performance analysis on a number of random routes. Specifically, a user can specify the number of random routes to be generated, and their run-times are recorded.

A box-plot illustrates the variation of these run-times and further explanation is provided to reveal further insights to which paths resulted in the fastest / slowest computation. An exemplar run led to the results is illustrated in Figure 5.

Once a route has more nodes to visit, then its computation time increases. The median run time to determine a route is around 0.2 seconds on a computer having Windows 10 with a i7 processor 2.60 GHz and 8 GB RAM.

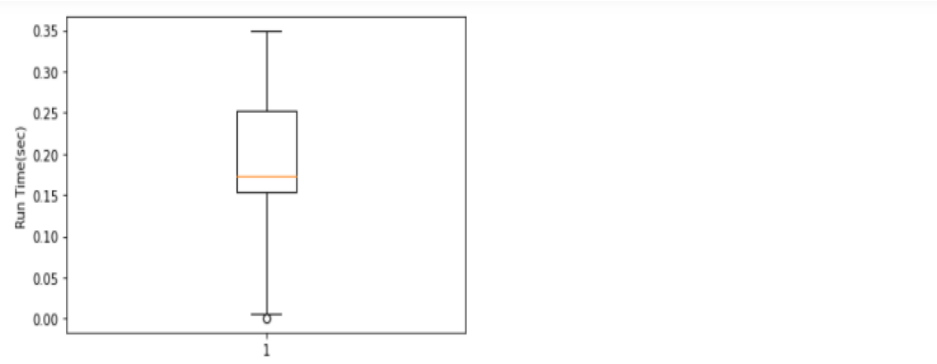

Figure 5. Run time analysis of 30 random routes with additional explanation on fastest and slowest run times

Furthermore, the resulting paths having the min/max run time is also stored as GeoJSON files under the *results/* folder. It is therefore straightforward to visualize these paths on QGIS by dragging and dropping the generated output files. A map produced with this approach is illustrated in Figure 6.

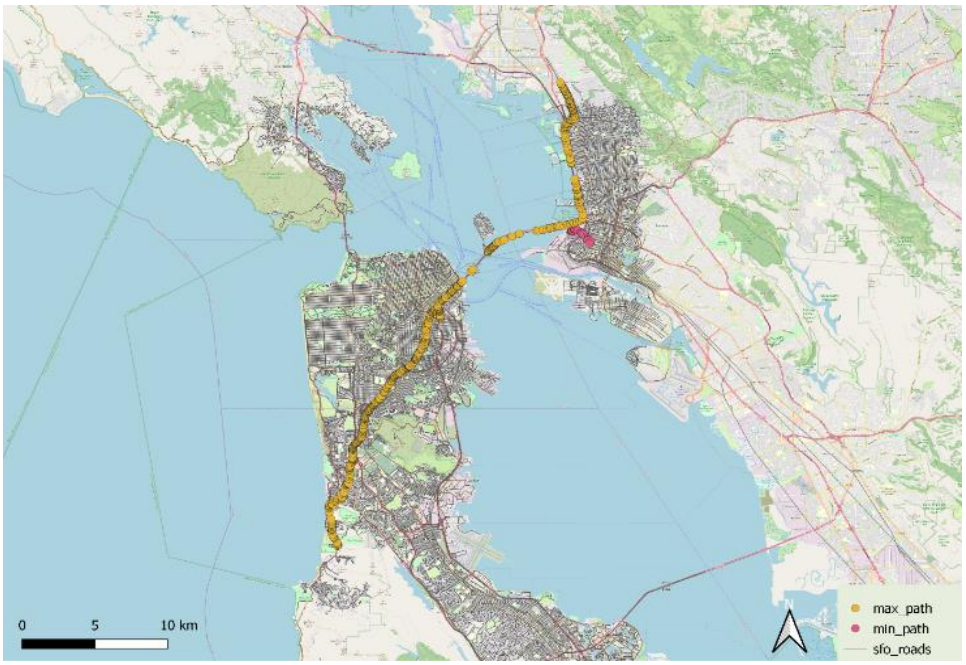

Figure 6. The least and the most time-consuming routes visualized in QGIS.

The ease of visualizing these paths allow a researcher/student to visually verify the outcome. Effective integration of the developed online material in a GIS Programming course should be investigated to further gain insights on its effectiveness (Anbaroğlu, 2021).

5. CONCLUSION

This paper developed an online education material to enable a researcher or analyst to understand how Dijkstra's algorithm works. The experimental setup is designed in a way to ease computational reproducibility. Specifically, open data and open-source software was relied on, and the developed code was implemented as a Jupyter Notebook that is hosted on GitHub. The future work will focus on the utilization of this educational material on a classroom setting, where students would be expected to find their own open dataset, and implement the Dijkstra's algorithm using a heap instead of relying on the readily available functions of NetworkX.

Author contributions

Muammer Özkan developed the code and contributed to the draft of the paper; Ayça Tabakoğlu and Ekin Gönenç Uygun wrote the draft of the paper and contributed to the code, and Berk Anbaroğlu did the supervision and completed the paper.

Conflicts of interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study.

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Spatio-Temporal Analysis of Climate Change in India: a Theoretical Perspective

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Keywords
Climate change,
Human life,
Agriculture,
Urban areas,
Health.

ABSTRACT

Climate Change has affected human activities directly and indirectly. There have been several causes and impacts of climate change. Due to climate change, there have been changes in the pattern of rainfall, rise in temperatures, evaporation, and salinization of sources of water due to rising sea levels. Glacial melting is increasing year by year. Climate change is due to the onservable but micro level alterations in the Earth's orbi that are responsible for changing the amount of solar energy the planet receives. satellites orbiting around Earth and other related technological advances have given a helping hand to the scientists to be able to capture remotely sensed data so that the planet can be studied from all the angles and aspects. Though climate change is a global concern, its effcets are being experienced all over the globe but, at varying degree. It will have negative impacts on agriculture, supply of wtaer, quality of air, coastal areas and health of people. India is the second largest country in terms of population and heavily depends on the various sectors like agriculture, fisheries, and forests which are sensitive to changes in climate. It is, therefore, bound to face the worst adverse impacts of climate change. Indirectly, climate change is disrupting global economies and is adversely affecting all forms of life, costing a lot since a long time and will continue to do so if strict actions are not taken to control the same. The present paper tries to enumerate the impacts of climate change in India.

1. INTRODUCTION

In different parts of the world, nomadic human tribes settled in Nile, 7, Euphratis, and Ganga etc. river valleys. They constructed for survival their houses in river valleys. Culture & civilizations developed in this region. Traditionally in the most of the developing an under developing countries, female population highly engaged in agriculture sector from cultivation to harvesting. Agriculture depends entirely on the environment for its survival & growth. All plants have certain basic requirements related to temperature, humidity conditions, soil etc.

The World Bank suggests that the districts that fall in central India show maximum vulnerability to changes in climate as they lack the required infrastructure and depend on agriculture on a very laregs scale. The districts in Vidarbha region of Maharashtra state are especially vulnerable to the damages caused by climate change. A major source for the decline in income of teh farmers has been teh cahnges in the climate. Increased temperature and disturbed precipitation is found to be damaging the crop yields and, consequently, the wealth of the farmers. Industrialization induced climate change, is the major cause of global warming and changing patterns of rainfall. Also, according to the estimation of the World Bank, unattended climate change would cause the Indian average temperature to rise to 29.1°C in the next few decades. As the aspect of changing climate becomes more intense, it will affect several parts of India extremely.

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When the average temperature in 2009-18 to the that in 1950-80 are compared, it is found that some pockets have already been affected by climate change by becoming hotter than before. In several parts of states like Rajasthan, Gujarat, Tamil Nadu, Kerala, and the North-East, it is observed that, there has been a rise of nearly 1° C in the average temperature during the last decade. İt is higher than the historical average in the 1950-80 period.

Natural and manmade activities dominants on the Earth surface. But climate change is a sudden and continuous global challenge. It has occurring long-term consequences for the development of all countries. Types of various pollutions, melting of ice in high altitude and Polar Regions, increasing sea levels of coastal areas, droughts and floods these problems created due to the climate change. Due to natural consequences of the influence of physical, cultural, technological and economic factors, agricultural land use and cropping patterns are changing from time to time. Climate change is general phenomena and important and facing environmental challenges.

Changes in climate ahve always been harmful to man. An increase of 0.3 - 0.6 ^{0}C is observed in the he average surface temperature of the globe since the several centuries. The rise in temperature may be minimal, but, it can be disastrous with unrepairable impacts. There are noticeable impacts of changing climate which occur in the form of melting of glaciers, forest fires, changing rainfall patterns, rising of sea levels, coastal cities under water level, floods, and droughts. Tsunami (2004), Uttarakhand flash floods (2013), Kashmir floods (2014), Kerala flood (2018 & 2019) and Krishna River Basin floods (2019) are some examples in various parts of India. India has been able to create a stable platform to discuss and bring in better cooperation between the nations on issus related to climate through its pledge for Paris Agreement. Also, India is an example by committing to bring down its emission intensity of gross domestic product (GDP) by 33-35% of 2005 levels by 2030.

2. METHOD

In the present study, the attempt has been made to assess the Spatıo-Temporal analysıs of Clımate Change in Indıa. This research paper is totally based on secondary data source. Climate change data collected from various articles, books, journals, reports and other related material published online and offline. The data contains the information such as mean temeperature, average rainfall, agirculture information, dieseas, urbnisation etc. The collected data are processed. cartographic technique, statistical and computer techniques used for preparation of graph.

2.1. Research objectives

- To understand the concept of climate change
- To study the major causes of climate change
- To administer the impact of climate change in India

2.2. Area of Study

India is a country in South Asia. It comprises of twenty-nine states and eight union territories. It's population stands second in the world after China. Its latitudinal extension is between 68^0 and 96^0 East and longitudinal extension is between 8^0 and 36^0 North approximately. It is a major developing country in the world and is the largest democracy too. It is highly agrarian in nature due to its fertile soil and favourable climatic conditions. It is however now being affected by changes in climate making it a matter of concern. Impact of climate change occurred on various condition is likely to have affected directly on agricultural food production and productivity, irrigation facilities, buildings and cities at coasts, human health, energy sources and security, etc. The major issue of maximum importance to developing and under developing countries is minimize the vulnerability of their natural, environmental and socio-economic condition. Natural hazards, like dry and wet droughts and floods in the plains threaten dangerous the livelihood of many people who depends on agriculture for most of their daily basic importance needs. External geographical events on the earth surface such as many types of cyclones, various droughts and floods, cold and heat waves, forest fires, landslips in the mountainous areas etc. are influenced frequently adversely on global economy.

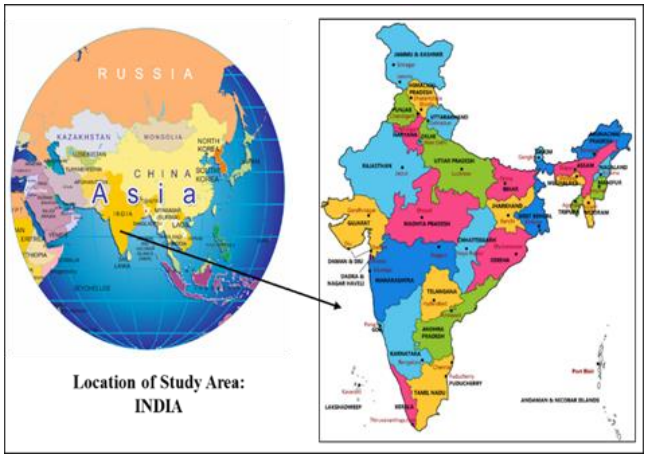

Figure 1. Location of India with States

2.2.1. Factors Leading to Climate Change Greenhouse Gases (GHGs)

Major source of climate change is greenhouse effect. The earth's surface warms due to the energy received from the Sun. Most (90 %) of the sun's insolation is absorbed by these gases and radiated back towards the surface. Out of the total energy passing the atmosphere, some of it gets scattered and only some of it gets reflected into the atmosphere from the surface of the Earth. Gases like CO2, methane, and Nox and water vapor, comprise less than 1% of the atmosphere. They are called 'greenhouse gases'. Human activities like decomposition of wastes in land fields, agriculture and rice cultivation and release of carbon dioxide during burning of fuels as coal, oil, and natural gas also lead to an increase in greenhouse gases. The climate of India is diversified.

Every state in India has its own characteristics. India is one of the leading economies in Asia. India is one of the major agrarian economies in Asia. India has a tropical climate. There are three seasons of summer monsoon and winter in India. The climate is different in each season, so different crops are produced in each state according to the season. In some states, tea, sugarcane and banana are perennial crops grown. Rainfall distribution in India is also uneven. Therefore, crop models are shown according to rainfall and irrigation facilities. Along the east and west coasts of India is a kingdom of rice-coconut orchards. Wheat mustard is grown in Punjab, Haryana and Uttar Pradesh. In Central India, cereals are produced from agriculture. Grapes, sugarcane, cotton, sorghum and pulses are generally important crops in Maharashtra and Karnataka. There are tea and coffee plantations in Assam, Meghalaya, Karnataka and West Bengal. In the hilly regions of eastern India, paddy is cultivated on hilly terraces. At the same time fruit processing industry is also important in India. The industry of making secondary products from seasonally produced fruits is found in all the regions of India.

Human Activities

Most of the population in India is engaged in agriculture. The agro based activities, various land-uses, etc., lead to rise in the levels of methane and nitrous oxide. Industries produce greenhouse gases like chlorofluorocarbons, whereas automobiles lead to ozone generation. According to 5th Report of IPCC, approximately 95 % human activities over the past 50 years led to global warming. İndustrialization and urbanization are major fcators in the process.

Emission of CO_2

Volcanic eruption is one of the most-deadly natural disasters on the Earth's surface. The eruption releases carbon dioxide (CO_2) in large quantities. It is also emitted through natural processes such as respiration and manmade activities like burning of fossil fuels. This gas directly impacts the environment and human beings.

Ocean currents

71% of the Earth's surface comprises of oceans and water bodies. Hot and cold ocean currents flow along all coastlines. The vast water bosies absorb the sun's insolation twice the atmosphere. Therefore, the oceans form a major component of the climate system.

Water vapour

Atmosphere is getting heated due to solar energy, because of which the amount of water vapor is increasing in the atmosphere day by day. Water vapor rises as the temperature of the Earth's atmosphere rises leading to precipitation. This cycle is very important for the smooth functioning of the ecology on globe.

3. DISCUSSION AND RESULTS

According to scientists, global temperature will continue increasing for few decades, due to the greenhouse gases emitted due to human activities.

Impact of Climate Change

From last few decades climate change in the world is caused by various types of economic activities. Day by day economic activities are increasing all parts of the world. When temperature rises, different changes occur on the Earth surface. Following are the some effects of climate change.

1. Due to the climate problems temperature can increased. Temperature directly affected in the fields of urban area, ice field region, deserts, coasts etc.
2. Dry and wet floods, droughts, cloudburst, cyclones etc. natural disasters occurs due to climate change.
3. Glaciers in the polar and subpolar regions are melting and levels of the sea is increasing.
4. Primary and secondary human economic activities are increased from last century, and these economic activities were released large number of carbon dioxide and other gases in the atmosphere.
5. Most of the gases in the environment come from burning fossil fuels and wood to produce energy.
6. greenhouse gases affected on human health, animal, agriculture and various types of Ecosystems.

Impact of Climate Change on Agriculture

The increasing population has resulted in scarcity of natural resources. Climate change has affected crop productivity due to alterations in temperature and rainfall. It has also caused changes in soil quality due to which the yield of cereals will decline in India. This scenario may lead to issues with food security and reduce dependancy on agriculture. In the field of agriculture, the future food security of people will influencing due to climate change. The climate sensitivity of agriculture is uncertain, as there is regional variation in rainfall, temperature, crops and cropping systems, soils and management practices. Due to the uneven and unseasonal distribution of rainfall in Maharashtra state in the year 199-98 number of crops losses. The northern and eastern part of Indian states experienced summer heat waves during the year 2003, and whereas northern part of Himalayan region was cold wave. Therefore production and productivity of the cash crops and local vegetables were loss. In the year 2004 due to high temperature food grain crops vegetables affected. Heavy rains again in September in Andhra Pradesh, Karnataka and Kerala led to floods and thus the year 2007 was declared as the flood year in India. A huge crop loss was noticed in several states of the Country due to floods in kharif, 2007.

Impact of Climate Change on Atmosphere

Climate change may affect health of human beingsas it increases ground-level ozone and the particulate matter causing air pollution. Ground-level ozone results in several health issues- diminished lung function, increased hospitalization and fatal incidences of asthma and premature deaths. It also causes extreme heat in the atmosphere which can lead to respiratory disorders.

Impact of Climate Change on Urbanization

India's urban system is the second largest on globe. It comprises of 310 million people spread across 5161 urban spaces in 2005. It is surprising to know that 5100 urban centers comprise roughly 30% of the total Indian population which is expected to rise to 40% by 2030. It is projected that the population of 70 urban spaces will rise to 1 million inhabitants by 2025.

Impact of Climate Change on Health

There are weak and low infrastructure facilities in developing countries. Climate change affects maximum particularly children, pregnant women and old people. It is expected that between 2030 and 2050, changing climate change may lead to death of 2,50,000 people every yera due to problems like malnutrition, malaria, diarrhea, and heat stroke. The following are the major impacts on human health.

It has resulted in the loss of glaciers, rise in sea level, huge floods, droughts, shifting of plant and animal ranges and a change in the pattern of floral reproduction and heat waves. Following are the impacts of climate change on environment and human life.

Table 1. State level annual and seasonal mean temperature trends based upon 282 surface meteoroligical stations for 1951-2010. Increasing (+) and decreasing (-) trends significant at 95% level of significance are shown in bold and marked with "*" sign.

	Mean Temperature Trends in Degree Celsius Per Year				
State	Annual	Winter	Summer	Monsoon	Post monsoon
Andaman and Nicobar Islands	**+0.01***	**+0.01***	**+0.01***	**+0.01***	**+0.01***
Andhra Pradesh	**+0.01***	**+0.01***	**+0.01***	**+0.01***	**+0.01***
Arunachal Pradesh	**+0.01***	**+0.02***	+0.01	+0.01	**+0.02***
Assam	**+0.01***	**+0.01***	No trend	**+0.01***	**+0.02***
Bihar	**+0.01***	No trend	No trend	**+0.01***	**+0.02***
Chhattisgarh	No trend	No trend	-0.01	No trend	+0.01
Delhi	**+0.01***	+0.01	**+0.01***	+0.01	**+0.02***
Goa	**+0.02***	**+0.02***	**+0.02***	**+0.02***	**+0.03***
Gujarat	**+0.01***	**+0.02***	+0.01	**+0.01***	**+0.02***
Haryana	No trend	-0.01	No trend	**-0.01***	+0.01
Himachal Pradesh	**+0.02***	**+0.02***	+0.01	**+0.03***	**+0.02***
Jammu and Kashmir	-0.01	No trend	-0.02	-0.02	**-0.02***
Jharkhand	**+0.01***	+0.01	No trend	No trend	**+0.02***
Karnataka	**+0.01***	**+0.01***	No trend	**+0.01***	**+0.01***
Kerala	**+0.01***	**+0.01***	**+0.01***	**+0.01***	**+0.01***
Lakshadweep	**+0.01***	**+0.02***	**+0.02***	**+0.01***	**+0.01***
Madhya Pradesh	**+0.01***	No trend	No trend	No trend	**+0.03***
Maharashtra	**+0.01***	No trend	**+0.01***	+0.01	**+0.01***
Manipur	**+0.03***	**+0.04***	**+0.02***	**+0.02***	**+0.03***
Meghalaya	No trend	**+0.01***	-0.01	No trend	**+0.02***
Mizoram	**+0.01***	**+0.02***	No trend	**+0.02***	**+0.02***
Orissa	No trend	No trend	No trend	**-0.01***	+0.01
Punjab	**-0.01***	**-0.02***	-0.01	**-0.01***	No trend
Rajasthan	**+0.01***	**+0.01***	No trend	+0.01	**+0.02***
Sikkim	**+0.05***	**+0.05***	**+0.02***	**+0.05***	**+0.04***
Tamil Nadu	**+0.02***	**+0.03***	**+0.03***	**+0.02***	**+0.02***
Tripura	**+0.01***	**+0.01***	**-0.01***	**+0.01***	**+0.03***
Uttar Pradesh	No trend	No trend	-0.01	No trend	**+0.01***
Uttarakhand	-0.01	+0.01	-0.02	**-0.02***	+0.01
West Bengal	No trend	No trend	**-0.01***	**+0.01***	**+0.01***

Source: Rathore, L., Attri, S. And Jaswal, A. 2013. State Level Climate Change Trends in India, GoI.

It is observed from table 01 that the annual mean temperatures of states of India have increased considerably in all the states. Only Chhattisgarh, Haryana, Jammu and Kashmir, Meghalaya, Orissa, Punjab, Uttar Pradesh, Uttarakhand and West Bengal do not show an increase. Sikkim (+0.05 o C/year) tops the chart followed by Manipur (+0.03 o C/year) and the least has been observed in Punjab (-0.01 o C/year). The major reasons for the change is the increase of carbon in the atmosphere and other greenhouse gases.

Table 02 represents that from 1901 to 2010, the highest fluctuations are observed in Meghalaya (+14.68 mm/year) and Andaman and Nicobar (-7.77 mm/year). The driving factors for changes in rainfall may include changes in wind direction and wind speed, occurrences of cyclones, changes in temperature, rate of evaporation and alterations in the land use of the areas. The changing trend implies that the states wiith high differences in average rainfall have undergone the above conditions and will continue to do so.

Table 2. State level annual and seasonal rainfall trends based upon 1451 rainfall stations for 1951-2010. Increasing (+) and decreasing (-) trends significant at 95% level of significance are shown in bold and marked with "*" sign

	Mean Temperature Trends in Degree Celsius Per Year				
State	Annual	Winter	Summer	Monsoon	Post monsoon
Andaman and Nicobar Islands	**-7.77***	**-2.70***	-0.51	-2.93	-1.35
Andhra Pradesh	+1.31	+0.29	+0.35	-0.14	+0.46
Arunachal Pradesh	-3.63	-0.10	No trend	-2.30	-0.83
Assam	-2.96	0.08	-0.56	-2.19	-0.75
Bihar	+1.41	-0.06	**+0.59***	+1.11	+0.11
Chhattisgarh	-2.03	+0.02	+0.04	-2.38	+0.06
Delhi	-0.51	+0.16	**+0.40***	-0.32	-0.20
Goa	-3.82	No trend	-0.31	-2.61	+0.04
Gujarat	+1.41	No trend	-0.03	+1.27	-0.02
Haryana	+0.45	+0.07	**+0.39***	-0.01	**-0.23***
Himachal Pradesh	-3.26	-0.18	+0.31	-2.85	-0.21
Jammu and Kashmir	+2.13	**+1.88***	-1.07	-0.16	-0.37
Jharkhand	+0.84	-0.13	+0.43	+0.44	+0.03
Karnataka	-0.05	+0.10	-0.41	+0.61	+0.14
Kerala	-1.43	-0.40	-1.15	-2.42	+1.68
Lakshadweep	+3.22	-0.33	-0.44	+1.73	+0.83
Madhya Pradesh	-1.81	-0.06	No trend	-1.74	+0.03
Maharashtra	-0.71	+0.04 -	0.15	-0.29	-0.05
Manipur	+1.94	+0.10	+1.63	-0.89	+0.11
Meghalaya	14.68	**+0.52***	+2.25	+9.27	+2.04
Mizoram	+0.33	-0.31	+2.80	+7.71	-6.19
Orissa	+0.69	+0.06	**+0.65***	-0.23	-0.83
Punjab	-2.41	+0.09	+0.22	-1.49	-0.13
Rajasthan	+0.04	+0.02	**+0.17***	-0.09	-0.04
Sikkim	-3.12	-0.12	-0.83	-1.36	-0.11
Tamil Nadu	+0.80	-0.16	-0.47	-1.35*	+1.49
Tripura	+0.77	+0.11	+1.73	-1.11	-0.55
Uttar Pradesh	-4.42*	-0.22	+0.02	**-3.52***	-0.33
Uttarakhand	-1.07	-0.01	+0.86	-1.45	-0.63
West Bengal	**+3.63***	+0.16	**+1.34***	+1.45	+0.19

Source: Rathore, L., Attri, S. And Jaswal, A. 2013. State Level Climate Change Trends in India, GoI.

Water borne diseases

Such diseases are vulnerable to climate change and represent variations according to changes in the season. Also, diarrheal diseases are another common occurrences during the monsoon season. Increased variability of rainfall as a result of climate change affect freshwater sources on a large scale globally. It is observed that scarcity of water has already affected 40% people all overe the Earth. Lack of clean water disturbs the hygiene and causes diarrheal diseases killing around 2.2 million people per year.

Flood borne diseases

Floods have become common all over the globe which contaminates several freshwater resources and increases the risk of water-borne diseases. If the contamination is due to animal waste, it leads to epidemics of leptospirosis, rotavirus and cholera in the affected areas. Absence of basic sanitation is a major factor in increasing water borne diseases.

Impact of Climate Change on Migration

Sudden changes in climate lead to migration of people as they become victims of droughts or floods in the rural areas. This leads to over crowding of the urban spaces and related impacts are experienced. In India, a large chunk of population is estimated to be affected by issues related to global warming in the near future. The major reason being the flooding of major rivers in certain parts and drying of the same in certain parts. This will lead to forced outmigration of people and cause haphazard development of urban areas with proliferation of larger slums with poor people.

Impact of Climate Change on Poor and the Vulnerable People

Climate and weather have a direct and indirect relationship with mankind. Vulnerable and poor populations are mostly affected by climate change due to higher food prices, loss of income, water scarcity, declining health and forced outmigration. The slum dwellers and other migrants and poor who generally live in vulnerable areas like the riverbeds, flood plains, hill slopes will be extremely affected.

Impact of Climate Change on Food Supply

Temperature is the main component of climate change. Rising temperature and uneven precipitation are responsible to decrease the production of staple crops. Ultimately it will increase the prevalence of malnutrition and under nutrition in most of the country.

Impact of Climate Change on Transportation

Transportation is very important to human life. Due to disasters like storms, floods, cyclones, coastal flooding, etc., a great damage is caused to the infrastructure of the affected area. The following graph shows that the carbon emission in India has always remained very high except the current year 2020 which may be due to the Coronavirus driven lockdown which has reduced the transportation and industrial activities to the minimum in the country. This is a good sign, however, as the activities will resume, the emission will increase again leading to climate change related problems.

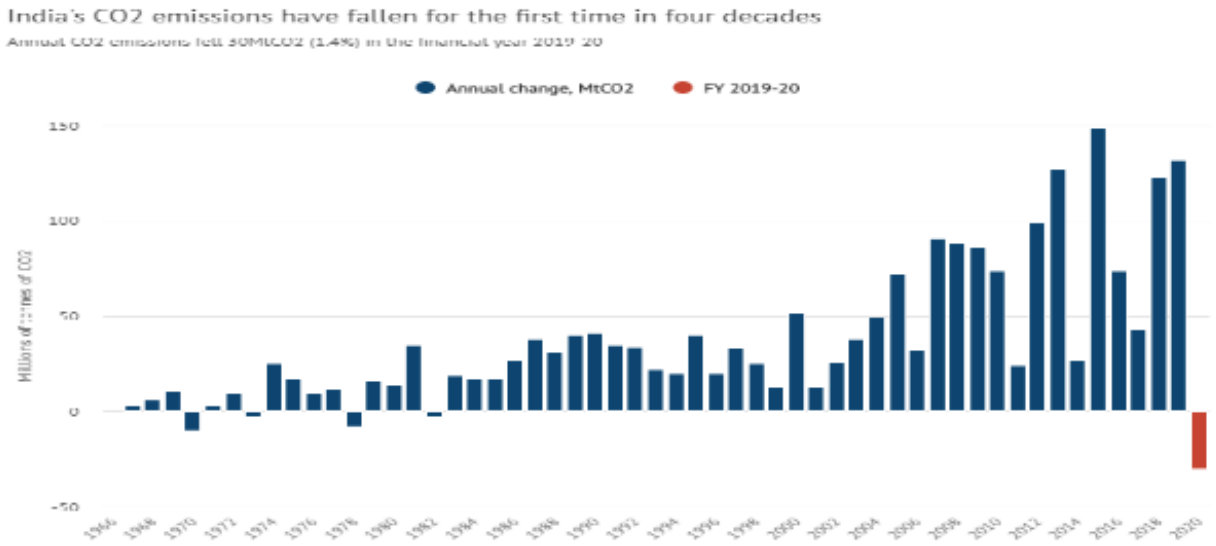

Figure 1. India's CO2 emissions have fallen fort he first time in four decades (Source: https://www.carbonbrief.org/analysis-indias-co2-emissions-fall-for-first-time-in-four-decades-amid-coronavirus)

Impact of Climate Change on Economy:

The World Bank estimates a loss of about 2% in National Gross Domestic Product of the country. It is a result of shortage of clean water and the damage caused to the sectors like agriculture and fisheries, tourism and energy. Therefore, it can be said that when the health is affected, the economy is also affected. For example, temperature and workable days are indirectly correlated to each other. Hence, increasing temperature will negatively affect the economy.

Impact of Climate Change on Coastal Area:

According to Aggarwal and Lal, the Indian coast is predicted to undergo a rise in sea level between 30 and 80 cm over the next century. If timely measures are not taken, then, the people living in coastal areas may get affected badly. The coastal cities of Mumbai, Kolkata and Chennai are at an average elevation of 2-10 meters and lie in the Low Elevation Coastal Zone (LECZ) category. Hence, they are most likely to suffer from flooding.

CONCLUSION

From the above, it can be concluded that, in the Indian continent, there has been an increase in the annual mean temperature during the last century. The predicted climate change reveals that the country will experience disastrous events that will enormously impact human life. It must be agreed that the climate is changing and it will surely lead to detrimental impacts in the entire coutry, continent and the world at large. Therefore, thinking about measures for mitigation and adaptation, both is equally important. Same is the case with developed nations who are trying hard to cope with the challenges posed by changing climate. However, with a very large an diverse population, India needs to put more efforts to counter the impacts. Climate is dominant on the Earth, where the man practices his agriculture from ancient period. Now a days occurs everywhere climate change phenomena. Its affected in the form of uneven distribution of rainfall and rising temperature. Climate is major component for the cultivation of all types of crops. Sudden climatic changes directly affected on the production of crops.

4. RECOMMENDATIONS

In India, about 70 per cent of the population is engaged in agriculture, agricultural labor and all kinds of agricultural occupations. That is why the Indian economy is said to be agrarian. In short, Indian agriculture is said to be the backbone of the Indian economy. According to tradition, people in India still practice agriculture in both traditional and modern ways. Some farmers farm to meet their food needs. Many farmers earn a living by doing commercial farming to meet their other needs. However, as Indian agriculture is depended particularly on monsoon, the effect of this climate on Indian agriculture is dominant. At the same time, in due to the development of co-operatives society's many states of India, have seen the flourishing of many agro based and other activates in agriculture. Co-operation is rooted in many of these states of India

Taking into consideration the increasingly changing climate, following are the recommendations to reduce the impact on human race-

- Boosting health care services
- Controlling the growth of vector
- Spreading awareness about health insurance
- Higher investment and greater research in climate change
- Undertaking health risk assessment studies
- Vulnerability mapping using GIS
- Establishment of baseline conditions
- Scenario modeling

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Author contributions

The authors contributed equally.

Conflicts of interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study.

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GNSS Frequency Availability Analysis

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Keywords
BeiDou,
Galileo,
GLONASS,
GPS.

ABSTRACT

In this study, three RINEX-3 daily observation data in 2021 were investigated in terms of the frequency availability of Global Navigation Satellite System (GNSS). All available frequencies in the RINEX-3 header were chosen to investigate for GPS, GLONASS, Galileo, and BDS data. The results showed that average frequency availability can be varied significantly among the frequencies and GNSSs. Availability of Galileo frequencies were found higher than the other GNSSs among the examined RINEX files.

1. INTRODUCTION

Global Navigation Satellite System (GNSS) has been used extensively for many applications such as navigation, deformation analysis, precise agriculture and etc. (Alcay et al, 2019; Guo et al, 2018). After the legacy GPS and GLONASS satellites, two newly emerged GNSSs, Galileo and BeiDou, became fully operational. Apart from these new GNSSs, the number of the new signal frequencies were also increased dramatically (Geng & Bock, 2013; Liu et al, 2019; Duong et al, 2019; Mutlu & Kahveci, 2019, Kaya et al., 2019). For more information the reader is referred to Chen and Chang, 2021.

Multiple frequencies sometimes become quite confusing, and users need to be aware that which frequencies should be chosen for processing. The emergence of the new signal frequencies was happen when the Receiver Independent Exchange Format (RINEX) 3.00 (https://files.igs.org/pub/data/format/rinex300.pdf) was introduced. RINEX 3.00 format and higher versions were especially designed for the frequencies of Galileo and BeiDou satellites. RINEX 2.00 format is the legacy format that cannot record all available GNSS frequencies (Wanninger, 2018; Yılmaz et al., 2016; Konak et al., 2020; Altuntaş & Tunalıoğlu). Despite the modernization of RINEX format, data loss frequently occurs due to the hardware and software limitations of GNSS receivers. This data loss can be divided into two categories as epoch data loss and frequency data loss. Sometimes, GNSS receivers cannot track all available epochs during the measurements due to the several reasons such as cycle slip, signal blockage and etc. Apart from the epoch data loss, sometimes GNSS receivers cannot track all available frequencies within the recorded epoch data. This data loss frequently causes some problems for navigation. For example, if the receiver cannot track the necessary frequencies within the particular epochs, navigation solutions cannot be conducted for these particular epochs.

In this study, we focused the frequency availability analysis for GPS, GLONASS, Galileo, and BeiDou GNSS data using three RINEX 3.03 format. The method of the estimated ratio of the available frequencies is described in the Materials and Methods section.

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2. MATERIALS and METHODS

In this study, three representative RINEX-3 daily observation data of three International GNSS Service-Multi-GNSS Experiment (IGS-MGEX) stations (CPNM, CKSV, and CKIS) were used for the frequency availability analysis of GPS, GLONASS, Galileo, and BeiDou satellites. When choosing the frequencies, all frequencies recorded in the RINEX headers were taken for each station.

Frequency availability percentages were computed as the number of available frequencies divided by the number of the theoretically available frequencies. If the recorded epoch includes the satellite PRN but doesn't include its frequencies (blank or zero), it means the frequency loss of this satellite.

Displays the frequency channels of each GNSS. For more information the reader is referred to https://files.igs.org/pub/data/format/rinex_4.00.pdf.

Table 1. Frequency channels of each GNSS

GNSS	Frequency channels
GPS	L1;L2;L5
GLONASS	G1;G1a;G2;G3
Galileo	E1;E5a;E5b;E5;E6
BeiDou-2	B1; B2; B3
BeiDou-3	B1; B2; B3; B1C; B1A; B2a; B2b; B2; B3A

As seen from Table 1, BeiDou-3 has the most frequency signals compared with the other GNSSs. In this study, L1/L2 (GPS), G1/G2 (GLONASS), E1/E5a (Galileo), and B1/B3 (BeiDou-2-3) frequencies were taken for the frequency availability analysis for phase and code observations.

3. FINDINGS

Table 2-5 summarize the average frequency availability of GPS, GLONASS, Galileo, and BeiDou GNSSs for three IGS-MGEX stations in 2021 (DOY: 100).

Table 2. Average frequency availability of GPS signals

GPS signals	Frequency availability (%)
C1C	99.7
L1C	99.5
C2W	94.6
L2W	94.4

Table 3. Average frequency availability of GLONASS signals

GLONASS signals	Frequency availability (%)
C1C	100
L1C	99.9
C2C	75.7
L2C	75.8

Table 4. Average frequency availability of Galileo signals

Galileo signals	Frequency availability (%)
C1X	100
L1X	100
C5X	99.2
L5X	99.2

Table 5. Average frequency availability of BeiDou signals

BeiDou signals	Frequency availability (%)
C1I	99.9
L1I	99.8
C7I	76.6
L7I	76.6

Commonly used dual frequencies phase (Lxx) and code observations (Cxx) were chosen for each GNSS as indicated above. As seen from the tables, Galileo has the most available frequencies compared to other GNSSs for the examined RINEX files. The less available second frequencies (75.6%) were computed for GLONASS satellites despite the availability of its first frequency was computed at nearly 100%.

4. RESULTS

The results covered in this study show that the frequency availability can be varied among the frequency channels and GNSSs. Two most used frequency channels were chosen to conduct frequency availability analysis for each GNSS. The results show that Galileo satellites have the most available frequencies compared to other GNSSs, and in terms of second frequencies, GLONASS satellites have the lower frequency availability for the examined three RINEX data in 2021, DOY 100.

Author contributions

Ceren Konukseven: Methodology, Writing-Original draft preparation.
Sermet Öğütcü: Writing-Reviewing and Editing, Validation.
Salih Alcay: Writing-Reviewing and Editing, Validation.

Conflicts of interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study.

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The Concept of Metaverse, Its Future and Its Relationship with Spatial Information

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Keywords
Metaverse,
Spatial information,
Virtual reality,
Augmented reality,
GIS.

ABSTRACT

The word Metaverse, which is described as the fictional universe, is formed by the combination of the words "meta" and "universe". This concept can also be expressed as a parallel universe where all digital media are integrated, in other words, everything that can be done on the internet is gathered on a single platform. In this study, detailed information about the concept of metaverse is given and evaluations are made about its future. In addition, detailed information about the relationship of spatial information with the metaverse, the place of Virtual Reality (VR) and Augmented Reality (AR) concepts in this process, territory/land purchase/sale in the metaverse environment, and the relationship of the metaverse with GIS are presented.

1. INTRODUCTION

Recently, many different technology companies in the world have invested in this field and it is mentioned that the future of the world will be shaped on this platform. As a word, metaverse also comes up with a meaning like “Metaverse” by combining the words “meta” meaning “after, beyond” in Greek and “universe” meaning “universe” in English (Teknosablog, 2022). However, the metaverse, which often means virtual universe, is also expressed as the perceptual universe that people feel completely mentally with augmented virtual reality devices without any physical effort. This universe; It enables human consciousness to be included in an artificial physical environment with the help of computers, android devices and 3D devices (Bilgile, 2022). Today, one of the most remarkable metaverse investors in the world is Facebook, which bought one of the companies working on virtual reality devices (Oculus) for 2 billion dollars (Arena, 2022). This concept has come to the fore even more with the beginning of Facebook's interest in the subject. Facebook, which has a huge data repository, has the metadata of millions of people. This gave rise to the concern that an artificial world based on artificial intelligence would threaten the individual borders of people (Bilgile, 2022). The company has changed its name to meta and has made cooperation agreements with important software companies such as Microsoft in this field. In addition, game platforms such as Roblox are making large R&D investments in this field (Bilgile, 2022). The metaverse is not fully implemented, but some platforms include metaverse-like elements. The closest experience to the Metaverse is currently offered by video games. Developers have expanded the concept of gaming by hosting in-game events and creating virtual economies (Binance Academy, 2022).

Metaverse promises to create a virtual public space. Virtual currencies of this public sphere are already traded in the cryptocurrency market today. In this respect, the concept of metaverse is seen as the future of the internet. The first city to enter this virtual universe called Metaverse is the city of Seoul. If this technology is sufficiently developed, people will have the opportunity to do many activities such as working, meeting with friends, shopping, going to the movies, spending time in cafes without any physical effort thanks to the virtual reality devices they have acquired (Kuş, 2021; Bilgile, 2022). Web 2.0 and Web 3.0 technologies that will enter our lives in the near future enable people to interact and communicate with each other in the virtual world (Teknosablog, 2022). Sometimes these two concepts seem to be the same, but they contain some differences.

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Because the concept of metaverse aims to move the dimension of interaction in this virtual world to a different place. With Metaverse, it is aimed to bring people into the digital universe created using Virtual Reality (VR) or Augmented Reality (AR) technology (Teknosablog, 2022).

Some researchers explain that Metaverse is taking up more and more space on the agenda with the effect of COVID-19 on digitalization (Kuş, 2021). It is stated that COVID-19 accelerates the transition to the digital world, which offers solutions regardless of the physical world and different variables (Kang 2021). Lee (2021) attributes the rise of the Metaverse to the continuity of non-face-to-face communication during the COVID-19 pandemic. On the other hand, although the pandemic is considered as a factor that can accelerate the transition to Metaverse, it should be noted that the technologies that form the basis of Metaverse have been in a natural development process for a long time and technology companies invest in technologies that can be used in the Metaverse universe (Kuş, 2021).

Cryptocurrencies, which have been popular from time to time in recent years and are still discussed, continue to be talked about extensively on the metaverse. Because, cryptocurrencies suitable for metaverse technology are starting to be created and it is stated that they will come to an important place in the metaverse in the future (Teknosablog, 2022). Blockchain applications like Metaverse allow people to earn money. Axie Infinity is a game played by many users to earn more income. Other successful examples are Second Life, which offers users a 3D virtual environment to socialize, learn and do business, and Decentraland, an online digital platform that combines social elements with cryptocurrencies, Non Fungible Tokens (NFT) and virtual real estate, with VR applications in the blockchain world. (Binance Academy, 2022). NFT is essentially a cryptocurrency. But in this definition, money can be any asset that has value outside of the definitions we know. That is, an NFT is a digital asset that has a value and can be collected. Assets that can be considered as NFTs; It can be any artwork, video, tweet, a web page, images, stories you create on social media and many more (İşbank Blog, 2022). NFTs are also used for LAND, which are 16x16 meter parcels of land that users can purchase with the MANA cryptocurrency on the Decentraland platform. In this virtual world, users purchase plots that they can later navigate, build on and earn money on (Bitlo, 2022). The combination of all this creates a complex crypto economy. The lands that connect the concept of metaverse with geographical location can be bought and sold on many different platforms such as Decentraland, The Sandbox, Somnium Space, OVR, SuperWorld and Axie Infinity, Bloktopia, Nexth Earth (Kılınç, 2022; Eryılmaz, 2021).

Decentraland: Decentraland, where Samsung has also opened its own store in the metaverse environment, is a platform consisting entirely of virtual lands. Here, the value of the lands generally increases as they get closer to Genesis Plaza, which is the central location. However, the size of the land, the buildings on the land and the objects it contains also increase the value of the land. (Kılınç, 2022).

The Sandbox: The Sandbox, the biggest competitor of Decentraland, is a digital platform where players create and sell their own plots just like Decentraland. The lands on The Sandbox also have different values according to the assets they contain (Kılınç, 2022).

Somnium Space: Unlike Decentraland and The Sandbox, Somnium, which offers VR support, allows you to create and design a land and buy and sell land, as in both games. The prices of the lands here also vary according to their location on the map and the value of the asset on the land (Kılınç, 2022).

OVR Land: This platform aims to bring the metaverse to the real world by separating itself from platforms such as Decentraland and The Sandbox. The lands taken on the platform, where a copy of the real world is created, can be shaped on the real world. The prices of the lands generally change according to the location of the land in the real world (Kılınç, 2022).

SuperWorld: Just like OVR, SuperWorld has brought a replica of the real world to the virtual world. The working logic of SuperWorld and the valuation of the lands take place just like in the OVR (Kılınç, 2022).

Axie Infinity: Axie Infinity, one of the most popular metaverse platforms, hosts developable plots that you can rent or buy. After owning one of these lands, the land can be traded by developing the land. The value of the lands here also varies according to the assets in the land, as in other platforms (Kılınç, 2022).

Bloktopia: Bloktopia, like other metaverse platforms, is built on the game and has much more advanced visuals than common metaverse games such as Decentraland and Axie Infinity. Acquiring real estate within the system also means being included in advertising revenues. This highlights the Bloktopia Metaverse platform as an important investment tool for the future. There are plots and billboards in Bloktopia. These plots and boards are being developed to be purchased with Blocktopia's own token, "Blok", and to shape and customize their land (Eryılmaz, 2021).

Nexth Earth: Next Earth is a global-scale physical world-based ecosystem that will evolve in four distinct phases. Land purchases are made. Next Earth is a blockchain-based metaverse community where users can buy and sell real-world places as land in a virtual world (Erel, 2022). Next Earth wants to bring a new groundbreaking frontier to the Metaverse. While several crypto projects are currently using VR/AR technology to create their own versions of the Metaverse, Next Earth aims to develop a fully Decentralized Autonomous Organization (DAO) controlled, interoperable and fully democratic Metaverse where users have real digital ownership over their avatars (Erel, 2022).

2. METHOD

In this study, information about the concepts of VR and AR as well as the concept of Metaverse is presented. Then, evaluations are made about the land/land relationship with the Metaverse and the geographical location of the land, as well as what spatial information means in terms of the metaverse. In recent years, we have witnessed rapid technological progress, the development of computer technology, and new digital

devices, tools and applications being developed almost every day. Rapid technological advances in hardware miniaturization and processing power are leading to the development of attractive devices that allow users and consumers to experience new "types of reality" (European Commission, 2017; Shen et al., 2022).

Digital technologies such as AR and VR have gained importance and popularity in recent years with technological developments (Ye et al., 2020; Shen et al., 2022). AR/VR applications are more widely used thanks to the number of enabling elements such as technological advancement (eg, processing power of computing and image, mobile internet and devices, interactive platforms) and creating meaningful content based on better understanding (Shen et al., 2022).). Although the concepts of VR and AR are similar to each other, they also contain significant differences. These differences are listed below (Pehlivan, 2021).

- While VR aims to provide an experience completely isolated from real life (Fig. 1), AR aims to build on real life and make it more interactive (Fig. 2).
- While in VR you live in the virtual world by disconnecting from real life, in AR you still live in the real world.
- While AR applications can be used like a mobile application, VR applications definitely need equipment that will cover your entire field of view and control what you hear.
- In VR, there is a completely recreated, simulated, non-existent environment, whereas in AR, the virtual does not replace reality, but on the contrary complements it. In other words, while VR places the user in an imaginary world consisting of digital images, AR technology places digital content on top of the visible physical world.
- The advanced dimension of AR is called Mixed Reality (MR). It is a combination of virtual and physical worlds under a single reality, with the help of wearable computers and various devices, to contain all the features of VR and AR technologies.
- In VR, you can move around and look up, down, sideways and back as if you were physically there. AR, on the other hand, consists of placing an information layer containing text or images on top of the real world in front of you, which appears on your phone's camera.

Figure 1. Virtual Reality glass (Nayır, 2017)

Figure 2. Augmented Reality (Apple, 2022)

3. RESULTS AND DISCUSSION

Human beings have always acted with the motive of owning a land or a product. Today's earnings systems are also built on this basis. In the metaverse environment, people are offered the opportunity to own land in a virtual environment similar to the real world.

Maps are considered as the basic tool in many computer games. In games such as Age of Empires, Civilization, Total War, Commandos and StarCraft, maps are used very effectively and determined strategies can be realized with the help of these maps. From this point of view, there is a high level of relationship with maps and spatial information in games played through platforms such as Axie Infinity, The Sandbox and Roblox in the metaverse environment. At the same time, lands can be bought and sold in these environments.

To purchase land on the Metaverse, a digital wallet must first be created. Afterwards, the companies selling virtual land can be searched and the desired plots can be purchased with the coins on the platform that sells the land or with cryptocurrency, the local currency of Metaverse, via the virtual wallet. Even the world-famous Samsung company has opened its own store on the Decentraland platform by moving its activities to the metaverse environment. In Decentraland, a platform consisting entirely of virtual lands, the value of the lands generally increases as they get closer to the central places. However, the value of the land, similar to the real world, may increase depending on the size of the land, the structures on the land and the objects it contains. In the metaverse environment, as in many countries, transactions such as buying/selling and renting virtual land on many different platforms, especially on metaverse platforms such as Decentraland and The Sandbox, are carried out through cryptocurrencies in our country.

Nexth Earth, one of the land sales platforms in the Metaverse environment, is similar to other land sales platforms. It is aimed to inform about other similar platforms by giving examples from this platform. By logging into the system with the e-mail address and the password specified on the platform called Nexth Earth, menus that will direct you to buy and sell land are encountered. The world consists of parcels with a certain area, such as pixels, on the map and represented by a tile (Fig. 3). A selection can be made on the map for the purchase of land (Fig. 3), or the plot that is planned to be purchased can be selected from among the plots in the sales announcement (Fig. 4). In addition, by entering the geographical location information in terms of latitude and longitude into the system, the determined land location and its vicinity can be selected (Fig. 5). The

prices of these plots are presented in matic metaverse coins. In addition, when clicking on the land, similar to a simple web-based GIS application, various information about that land such as price per tile, current owner, purchased for, and total price can be accessed (Fig. 5). Again, previously purchased lands/territories can be accessed (Fig. 6).

Figure 3. Land purchase on the Nexth Earth platform (Nexth Earth, 2022)

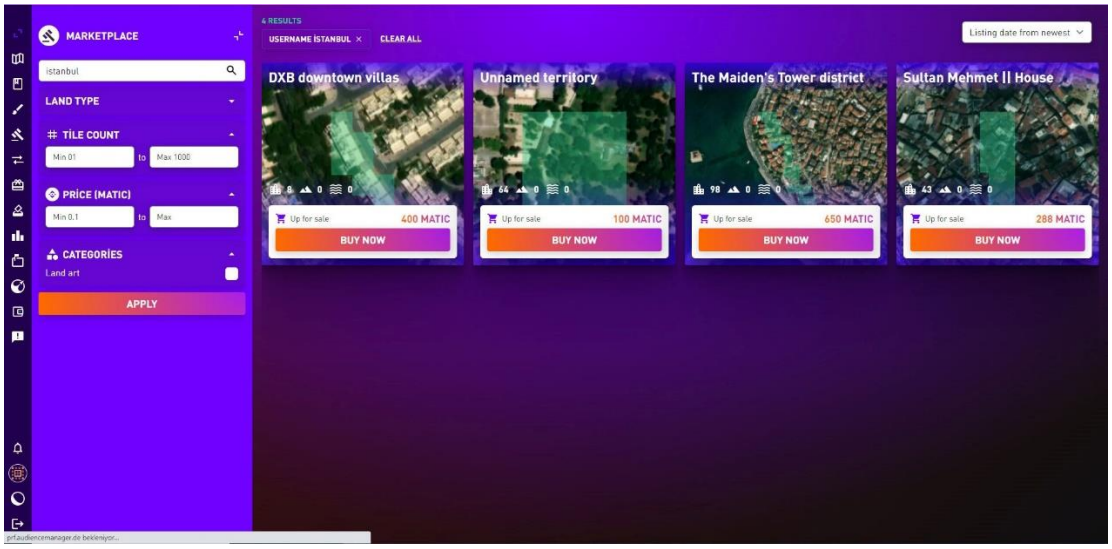

Figure 4. Land/territory for sale on Nexth Earth platform (Nexth Earth, 2022)

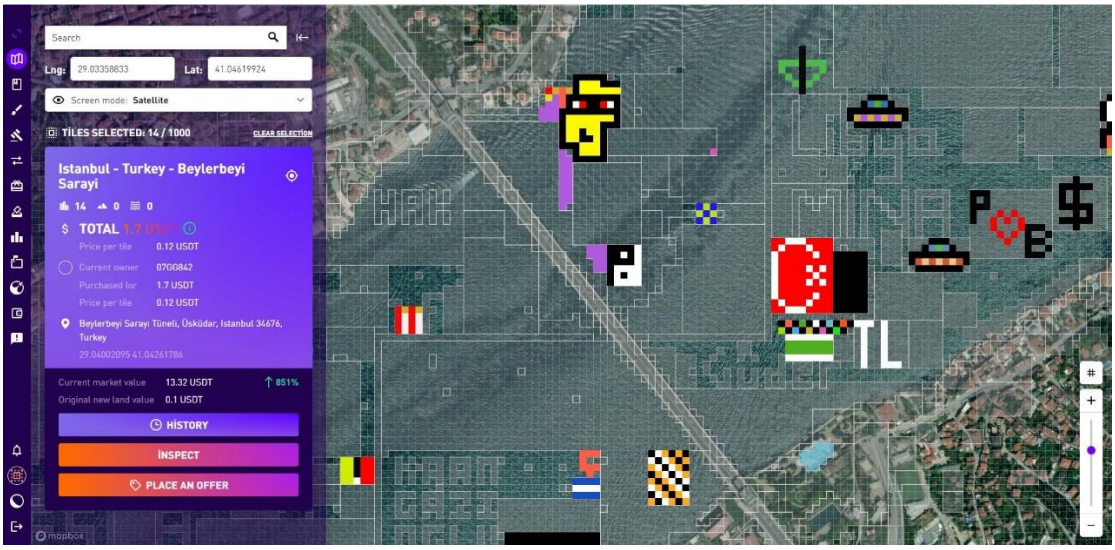

Figure 5. Access to information on land sold by query on the Nexth Earth platform (Nexth Earth, 2022)

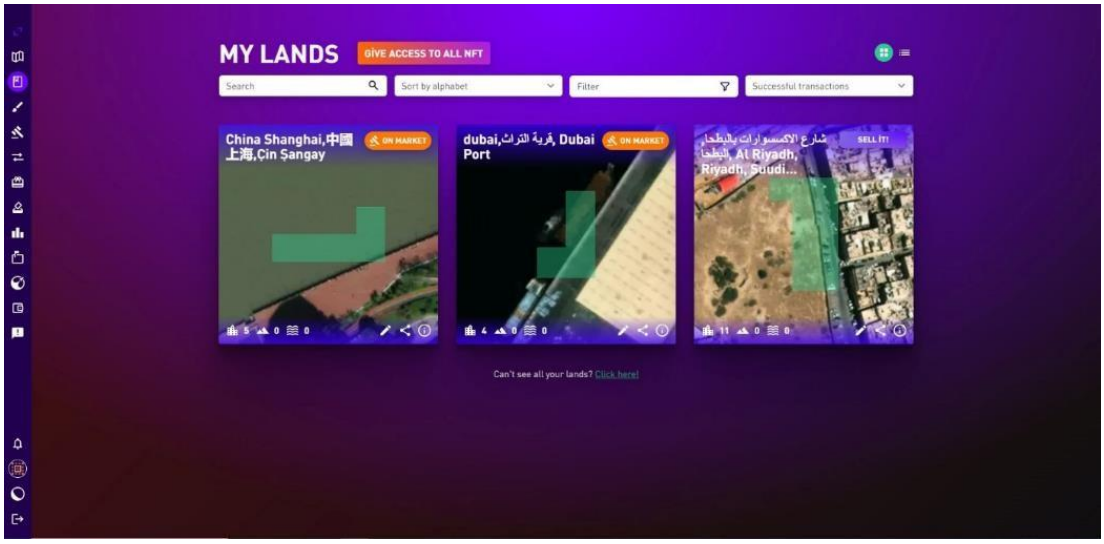

Figure 6. Land/territory purchased on the Nexth Earth platform (Nexth Earth, 2022)

Metaverse environment has started to be seen as an investment tool day by day. Lands that are thought to be valuable in the coming years by people with this mindset can be purchased in advance and invested in these areas. The optimum site selection problem is one of the most widely used analysis series in GIS applications. After the land is purchased through Metaverse land sales platforms from the regions determined using these analyzes, these investments can be profited by auction or different sales methods. Of course, this parameter alone may not be enough for gain. However, parameters such as the size of the land, the location of the land in the real world, the transportation and accessibility of the land, the right timing for buying and selling can also affect this gain.

4. CONCLUSION

The digital age, which has made a rapid transition with the COVID-19 process, deeply affects the traditional life of human beings. With the digital age, different from traditional life, concepts such as remote learning and remote meeting have begun to enter our lives. In addition to these concepts, we are witnessing more frequently that business life and socialization are moved to the virtual environment in terms of some sectors. In such a blockchain-based world, it is inevitable that the concept of Metaverse will be encountered more and more frequently. Taking part in the world that includes this newly developing concept may provide us some benefits in the coming period.

The existence of geographical information, which is used effectively in the concept of metaverse, which is the subject of this study, shows that GIS will be used effectively in this environment in the coming period. The power of spatial information can be utilized more effectively in this environment.

In this study, the concept of metaverse was examined and its relationship with spatial information and GIS was revealed. In this process, the future of the concept of metaverse and the place of spatial information and GIS in the concept of metaverse have been tried to be discussed.

Author contributions

The entire article was contributed by Tarık TÜRK.

Conflicts of interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

This study complies with the rules of research and publication ethics.

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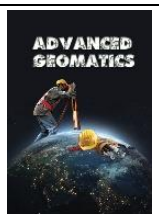

The Current State of Use of Satellite-Based Positioning Systems in Turkey

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Keywords
Satellite Based Geolocation,
Satellite Signal,
Signal Receiver.

ABSTRACT

Nowadays, the cartography sector has also been affected by the rapid developments in the field of technology. Recently, satellite-based positioning systems have been used instead of the classic land measurements made with total station and engineer's level. In this study, the general structure of satellite-based global and regional positioning systems is examined. The general usage densities of the system in the public and private sectors in Turkey and the status of the signals that can be received and the average sales prices of devices on the market have been investigated. The results were presented in the form of tables and graphs, and it was found that the most ideal device for our country is the device called Kolida K58 Pus, which can work with systems such as GPS/GLONASS/SBAS/GALILEO/QZSS/BEIDOU and receive signals from many satellites of these systems.

1. INTRODUCTION

Mankind has always wanted to improve itself in the field of communication from the very beginning of its existence. It has used a different communication method in each cycle by producing new communication systems. After a while, satellites were sent to space and satellite-based communications began. Today, satellites are widely used both for communication and for providing location data. In this study, the number of satellites seen by devices using the data of satellite-based positioning systems and the variety of signals it can receive from these satellites are presented as tables and graphs. Then, with the help of the relevant tables and graphs, recommendations were made about which brand and model could be the most suitable GNSS buyer for our country (Yılmaz et al., 2016; Mutlu & Kahveci, 2019).

Today, there are 6 satellite-based positioning systems operating at full capacity or under construction. GPS is the first satellite-based positioning system. The GPS program was initiated by the US Department of Defense in the 1970s. GLONASS is the second system to reach full capacity, operated by Russia. GLONASS's constellation consists of 24 satellites and provides global coverage. Of the 25 GLONASS satellites currently in orbit, 1 is in the testing phase, while the other 24 are operational. Galileo is a civilian system operated by the European Global Agency for Navigation Systems (GSA). The satellite set, whose first satellite was launched in 2014, is planned to be completed in 2020. The satellite set consists of 7 satellites. QZSS is a regional positioning system serving Japan and the Asia-Oceania region (Kaya et al., 2019; Konak et al., 2020). The satellite set, which currently consists of 4 satellites, will be completed to 7 after 2023 and will be able to serve as an independent system [URL-1].

In this study, first of all, the structure of satellite-based positioning systems will be introduced. Afterwards, the structure, capacity and number of satellites that can receive the signals of these GNSS systems will be presented graphically (Altuntaş & Tunalıoğlu, 2022). As a result, the most ideal satellite system for Turkey will be determined.

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2. SATELLITE BASED POSITIONING SYSTEMS STRUCTURE and COMPONENTS

2.1. GPS

The GPS system was originally designed for military requirements. Its design was partially developed in the early 1940s, after World War II. It is based on similar ground-based radio-navigation systems such as LORAN (LORAN - Long Range Navigation) and Decca Navigator, which was a solution for that period used during World War II and then used for a long time. The first use of GPS dates back to just after the Second World War. The system was designed to be used in navigation with signal receivers, in military plans and position calculations, and in the control of guided rockets. The GPS system was opened for civilian use only in the 1980s [URL-2].

2.1.1 Space Division

The space segment consists of at least 24 satellites (18 active and 6 standbys) and is the center of the system. The satellites orbit 20,000 km above the earth's surface, called "High Orbit". Satellites at such heights have a very wide field of view and are placed in such a way that a GPS receiver on Earth can always see at least 3 satellites for two-dimensional determination and at least 4 for three-dimensional determination. They run on solar energy and are designed to be used for at least 10 years. It also has backup batteries in case of solar power outages and small igniter rockets for orbit corrections [URL-2].

2.1.2 Control Section

In satellites, timing is provided by 4 atomic clocks (2 rubidium and 2 cesium). These clocks measure the oscillation of cesium and rubidium atoms, and therefore time. Small deviations in satellite orbits may occur. To calculate these deviations, the control section satellites continuously monitor the orbital information. This obtained error transmits the data to the main control center and correction messages must be uploaded to the satellites at regular intervals [URL-1].

2.2 GLONASS

GLONASS, which stands for "GLObal'naya NAvigatsionnaya Sputnikovaya Sistema (Global Navigation Satellite System)", is a space-based satellite navigation system that provides both civil and military service operated by the Russian Aerospace Defense Forces. It is planned to consist of 24 operational satellites rotating in 3 different orbital planes at an altitude of 19100 km. The system as an alternative to GPS; It is the second satellite-based navigation system with global coverage and comparable sensitivity. The development of GLONASS is somewhat delayed, but parallels GPS. The system, which started to provide military service with 12 satellites since 1993, reached full operational capability in 1995 with the completion of the main satellite set consisting of 24 satellites [URL-3].

2.2.1 GLONASS Space Division

GLONASS is a satellite-based positioning system with global coverage, whose main constellation consists of 24 medium orbiting satellites. The satellites in the GLONASS constellation are placed in 3 orbital planes close to the earth-centered circular orbit. 24 satellites are deployed in 3 orbital planes with 8 satellites in each. The orbital tilt angle of the orbital planes is 64.8 degrees. Each satellite completes one orbit in 11 hours 15 minutes 44 seconds. The track of the orbits is repeated every 17 revolutions (8 days). The chosen orbital period ensured that the satellites did not need orbit correction during their active life; Unlike GPS, it allowed the creation of a sustainable orbital system [URL-3].

2.2.2 GLONASS Control Section

The GLONASS control segment consists of a system control center, two central clock facilities and a network of command and tracking stations distributed over Russia. In the network of command and tracking stations; telemetry, tracking and command stations (TT&C), upstream data stations, unidirectional tracking stations and laser distance measuring stations (SLR). Updates are uploaded to the satellites twice a day. The system control center responsible for the planning and coordination of all ground segment components is located in Kraznosnamensk, near Moscow. The central clock consists of the main plant in Shelkovo and the supplementary plant in Komsomolsk. In each of these facilities, 4 hydrogen masers are used for the continuity of the GLONASS system time [URL-3].

2.3 GALILEO

2.3.1 GALILEO Space Division

Galileo's satellite suite, which is a positioning system with global coverage, consists of a total of 30 medium-orbiting (MEO) satellites, 24 of which are main and 6 are backup. The Galileo constellation was initially planned to consist of 27 active satellites and 3 standby satellites to meet the Safety of Life (SoL) service requirements. In 2012, these services were rearranged and it was decided to use 24 active and 6 backup satellites in the system. Satellite sequences in orbits have been changed accordingly [URL-4].

2.3.2 Galileo Control Section

Galileo control segment; It consists of 2 ground control centers and 3 different station networks with global spread. It is divided into two separate sub-segments in the Galileo control segment. The control of the satellite team is performed by the Ground Control Segment (GCS), while the service-related tasks are performed by the Ground Mission Segment (GMS). The Galileo ground segment, which is under construction, is being built in partnership with Thales-Alenia Space (France, Italy) and Airbus Defense and Space (England, France). Ground Control Segment (GCS); performs all operations related to the command and control of the satellite team. Ground Control Segment (GCS); It consists of a Ground Control Center (GCC) and Telemetry, Monitoring and Command Facilities/Stations (TTCF/TT&C) [URL-4].

2.4 BEIDOU

BeiDou means "Big Bear Constellation" in Chinese. The Ursa Major is considered to be the most important constellation that enables people to navigate in the northern hemisphere. When China decided to establish its own satellite-based navigation system, this name was chosen naturally, but the English name of the system was COMPASS for many years. Deciding to develop its own independent satellite-based positioning system in the 1980s, China planned the construction of the system in three stages. Thus, China became the third country to establish an independent satellite-based navigation system after the USA and Russia. In the second phase, called BeiDou-2, it is aimed to establish a regional satellite-based positioning system. The system, which will consist of a total of 35 satellites with 27 mid-orbit, 3 inclined geosynchronous orbits and 5 geostationary orbits, is expected to be completed approximately in 2020 [URL-5].

2.4.1 BeiDou Space Division

The BeiDou Navigation Satellite System is being developed in three phases. Three experimental positioning satellites were launched in BeiDou Phase I, which aims to demonstrate technology. Within the scope of BeiDou Phase II, a regional satellite-based positioning system was established. When these satellites reached the end of their design life, they were replaced with second generation satellites. The signals emitted by the BeiDou satellite team were named with the first letter of the system "B". BeiDou-2 regional satellite-based positioning system; It transmits navigation signals to the earth in the B1, B2 and B3 bands [5].

2.4.2 BeiDou Control Department

The components of the BeiDou ground segment, called the Operational Control Segment (OCS), are scattered over mainland China. BeiDou control segment; It consists of 1 main control station, 29 monitoring stations and 2 upstream data transmission stations. There are two types of tracking stations in the system. Type A tracking stations are used to monitor orbital and ionospheric delays. There are 7 of these stations. The remaining 22 monitoring stations are of type B. These stations are; They provide support and integration services. Data sending stations are used for time synchronization and data upload (URL-5).

2.5 QZSS

Japan, which uses GPS extensively, continues its efforts to establish a regional positioning system called the Quasi-Zenith Satellite System (QZSS) in order to solve the problems encountered during the use of GNSS in dense urban areas and to create its own satellite-based positioning capability. The main purpose of Japan to start the QZSS project is to reduce the errors caused by signal shadowing and reflection, especially during the use of GPS in cities. The Quasi-Zenith orbital set, which gives the system its name, ensures that there is always at least one satellite with an elevation angle of 60 degrees and above over Japan. The main purpose of this is to reduce the error rate due to reflection and atmospheric effects, and to increase positioning accuracy and consistency. QZSS satellites can also act as additional GPS satellites; It can work integrated with GPS. The system, the first satellite of which was launched in 2010, is expected to reach full operational capability in 2018 [URL-6].

2.5.1 QZSS Space Division

QZSS consists of 3 Quasi-Zenith orbiting (QZO) satellites and one Geostationary orbit (GEO) satellite. The geostationary satellite follows a circular orbit at an altitude of about 36000 km above the equator. The orbital period of the satellite, which has a constant speed of about 3 km / s, is about 24 hours and rotates simultaneously with the earth The orbital speed of the satellites is around 3 km/s. The orbital periods, which are about 24 hours, are synchronized with the rotation of the earth, as in the Earth-Stationary orbit. As a result, their projections on the earth during their movements draw an "8" shape. When viewed from the ground, it is seen that they follow an orbital path in the form of "8". The Quasi-Zenith orbit is set for the satellites to stay over Japan for an extended period of time [URL-6].

2.5.2 QZSS Control Section

The ground segment of QZSS consists of 2 main control stations, 7 satellite control stations and over 30 monitoring stations around the Earth. QZSS has two main ground stations. These stations, which act as control centers, are located in two different campuses. The main station from which the operation is conducted is located in Hitachi-Ota. There are 25 Precision Orbiting stations for GPS and QZSS satellites around the world. Three of these stations are in Japan. In addition, there are 10 Sub-Meter Level Support Service (SLAS) stations in Japan. For QZSS's Centimeter Level Support Service (CLAS), Japan's Continuous Employee Service with more than 1,300 stations. Reference Stations (CORS) network GEONET (GNSS Ground Observation Network System) is used [URL-6].

2.6 IRNSS

2.6.1 IRNSS Space Division

The NavIC constellation consists of 7 satellites. 3 of the satellites are in geostationary orbit and 4 of them are in inclined geosynchronous orbit. While designing the said satellite set; Attention has been paid to minimizing the loss of sensitivity (DOP value), maximizing the number of satellites that can be seen over the targeted area, using the least possible number of satellites, ensuring system sustainability in case one of the satellites fails, and orbital positions to be used are suitable. All of the satellites in the NavIC constellation are constantly visible from the Indian region [URL-7].

2.6.2 IRNSS Control Section

The ground segment is responsible for operating and maintaining the IRNSS constellation. In this context; 15 IRNSS Distance and Integrity Monitoring Stations (IRMS), 4 IRNSS CDMA Distance Measurement Stations (IRCDR), 2 IRNSS Spacecraft Control Facility (IRSCF), 1 IRNSS Network Timing Facility (IRNWT), 1 IRNSS Navigation Center (INC) was established [URL-7].

3. STRUCTURE AND COMPONENTS OF SATELLITE-BASED POSITIONING SYSTEMS

The GPS system, first developed in the early 1940s for military requirements, was developed during World War II. It is based on similar ground-based radio-navigation systems used during World War II, such as LORAN (LORAN - Long Range Navigation) and the Decca Navigator, which later became a solution for that period. The first use of GPS was intended for use in military plans and for the control of guided rockets. The GPS system was opened for civilian use only in the 1980s [URL-1, 2].

GLONASS operated by the Russian Aerospace Defense Forces, both civilian and military-service space-based satellite navigation system. Although the development of GLONASS is somewhat delayed, it has parallels with GPS [URL-3]. GALILEO's satellite team, a positioning system with global coverage, consists of a total of 30 mid-orbit (MEO) satellites, including 24 main and 6 backup ones. The GALILEO satellite team was originally planned to consist of 27 active and 3 reserve satellites in order to meet the Life Safety (SOL) service requirements [URL-4].

BeiDou means “Big Bear Team Star” in Chinese. The Big Bear is considered to be the most important star team that allows people to find direction in the northern hemisphere. Although this name was naturally chosen when China decided to create its own satellite-based navigation system, the COMPASS name was used as the English name of the system for many years [URL-5].

GPS-intensive, Japan, in dense urban areas and resolve their own problems encountered during the use of GNSS satellite-based positioning capability to create Quasi-Zenith Satellite System (QZSS) is called to establish a regional positioning system continues to work. QZSS satellites can also act as additional GPS satellites and work in an integrated way with GPS. The system, the first satellite of which was launched in 2010, is expected to reach full operational capability in 2018 [URL-6].

The NavIC satellite suite consists of 7 satellites. 3 of the satellites are in an earth-stationary orbit, and 4 are in an oblique earth-synchronous orbit. When designing the satellite set in question, attention was paid to minimizing the sensitivity loss (DOP value), maximizing the number of satellites visible over the targeted area, and using the fewest possible satellites. All of the satellites in the NavIC satellite suite are constantly visible from the Indian region [URL-7].

4. EXPERIMENTAL METHOD

The current use status of satellite-based position systems in our country, public and private sector users have been contacted by phone, website and mail to determine which of their respective devices have seen how many satellite systems and which signals they have received. The obtained results are given in Table 1.

Table 1. Current status of satellite-based position sites in Turkey

Companies	Devices	Used Satellite Systems	Monitored Signals
KAYA HARİTA MÜHENDİSLİK	e-survey E600	GPS /GLONASS /BeiDou /Galileo /QZSS /NAVIC /SBAS	L1 ,L1P,L1C,L2P,L2C,L5 / G1,G2,P1,P2 / B1,B2,B3 / E1BC , E5A,E5B /L1,L2C,L5,L1C / L1 ,L5 /WAAS,EGNOS,MSAS,GAGAN
PAKSOY TEKNİK MÜHENDİSLİK	Topcon Hıper HR	GPS /GLONASS /BeiDou /Galileo /QZSS /NAVIC /SBAS	L1,L2,L2C,L5/L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2C,L5,L6 / L5 /WAAS,EGNOS,MSAS,GAGAN
SİSTEM A.Ş.	Leica Viva GS16	GPS /GLONASS /BeiDou /Galileo /QZSS /NAVIC /SBAS	L1,L2,L2C,L5/L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2C,L5,L6 / L5 /WAAS,EGNOS,MSAS,GAGAN
SİSTEM A.Ş.	Leica GS18 T	GPS /GLONASS /BeiDou /Galileo /QZSS /NAVIC /SBAS	L1,L2,L2C,L5/L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2C,L5,L6 / L5 /WAAS,EGNOS,MSAS,GAGAN
BAYTEKİN MÜHENDİSLİK	Sanding Aquila T66 PRO	GPS /GLONASS /BeiDou /Galileo /QZSS /NAVIC /SBAS	L1,L2,L2C,L5/L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2C,L5,L6 / L5 /WAAS,EGNOS,MSAS,GAGAN
GEOMATİK HİZMETLER	Geomax Zenith 40	GPS /GLONASS /BeiDou /Galileo /QZSS /NAVIC /SBAS	L1,L2,L2C,L5 /L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,altboc,E6/L1,L2C,L5,L6/L5/EGNOS,WAAS,MSAS,GAGAN
SİSTEM A.Ş.	Leica GS07	GPS /GLONASS /BeiDou /Galileo /QZSS /NAVIC /SBAS	L1,L2,L2C,L5/L1,L2,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2,L5,LEX / L5 /WAAS,EGNOS,MSAS,GAGAN
GEOMATİCS GROUP	Spectra Geospatial SP85	GPS /GLONASS /BeiDou /Galileo /QZSS /NAVIC /SBAS	L1 C/A ,L1P,L2C,L2P,L5 / L1 C/A,L1P,L2 C/A,L2P,L3 /B1,B2 /E1,E5a,E5b/ L1 C/A,L1C,L2C,L5 / L5 / L1 C/A,L5
GEOTEKNİK MÜHENDİSLİK	Kolida K58 Pus	GPS /GLONASS /SBAS /GALİLEO /QZSS /BEİDOU	L1C/A, L1C, L2C, L2E, L2P, L5 /L1C/A, L1P, L2C/A, L2P, L3 / L1 C/A, L5 /GIOVE-A ve GIOVE-B, E1 , E5A, E58, E5AltB0C, E6 /L1C/A. SAIF, L1C, L2C, L5, LEX /B1,B2,B3
KAYA HARİTA MÜHENDİSLİK	e-survey E300 PRO	GPS/GLONASS/BeiDou/Galileo /SBAS/QZSS	L1 C/A ,L1P,L1C,L2P,L2C,L5 /G1,G2,G3 / B1L,B2L,B3L,B1C,B2A,B2B,ACEBOC /E5A, E5B, E5AltBOC, E6 /L1,L5 /L1 C/A,L1C,L2C,L5,LEX
SİSTEM A.Ş.	Leica GS18 I	GPS/GLONASS/BeiDou/Galileo /QZSS/SBAS	L1,L2,L2C,L5/L1,L2,L2C,L3/E1,E5a,E5b,AltBOC,E6/B1I,B1C,B2I,B2a,B3I/L1,L2C,L5,L6/WAAS, EGNOS,MSAS,GAGAN L-bant
GEOTEKNİK MÜHENDİSLİK	Kolida K1 PRO	GPS /GLONASS /QZSS /GALİLEO /SBAS /BEİDOU	L1C/A, L1C, L2C, L2E, L5 / L1C/A, L1P, L2C/A, L2P, L3 /L1 C/A, L5 /GIOVE-A ve GIOVE-B, E1, E5A, E5B, E5AltBOC, E6 /WAAS, MSAS, EGNOS, GAGAN /B1, B2,B3
GEOTEKNİK MÜHENDİSLİK	South Galaxy G6	GPS /GLONASS /QZSS /GALİLEO /SBAS /BEİDOU	L1C/A, L1C, L2C, L2E, L5 / L1C/A, L1P, L2C/A, L2P, L3 /L1 C/A, L5 /GIOVE-A ve GIOVE-B, E1, E5A, E5B, E5AltBOC, E6 /WAAS, MSAS, EGNOS, GAGAN /B1, B2,B3
PAKSOY TEKNİK MÜHENDİSLİK	Topcon MR-2	GPS /GLONASS /BeiDou /Galileo /SBAS /QZSS	L1 C/A , L1C,L1P,L2P,L2C,L5 / L1 C/A ,L1P,L2 C/A,L2P,L3C / E1,E5a,E5b,AltBOC /B1,B2 /WAAS,MSAS,EGNOS/L1 C/A,L1C,L2C,L5C
EKSEN TEKNİK	FOİF A90	GPS / GLONASS/ BEİDOU / GALİLEO /SBAS/QZSS	L1 C/A ,L1P , L1C ,L2P , L2C ,L5 / G1,G2,P1,P2 / B1,B2,B3 / E1BC, E5a,E5b,E5AltBOC ,E6 / L1,L5 / L1 C/A ,L2C, L5,L1C
GEOTEKNİK MÜHENDİSLİK	South Galaxy G1	GPS /GLONASS /SBAS /GALİLEO /QZSS /BEİDOU	L1C/A, L1C, L2C, L2E, L5 /L1C/A, L1P, L2C/A, L2P, L3 / L1 C/A, L5 /GIOVE-A ve GIOVE-B, E1 , E5A, E5B, E6altB0C /L1C/A, L1C, L2C, L5 /B1,B2,B3
SATLAB GEOSOLUTIONS	Satlab SLC	GPS /GLONASS /SBAS / BeiDou /GALİLEO /QZSS	L1 C/A, L1C,L2P,L5 /L1,L2 / WAAS,EGNOS,MSAS,GAGAN/B1,B2/E1,E5a,E5b,AltBOC/L1,L2C,L5,L6

Table 1 (continued).

GEOMATİCS GROUP	Spectra SP60	GPS /GLONASS /BeiDou /GALİLEO /QZSS /SBAS	L1 C/A ,L1P,L2C,L2P,L5 / L1 C/A,L1P,L2 C/A,L2P,L3 /B1,B2 /E1,E5a,E5b/ L1 C/A,L1C,L2C,L5 / L1 C/A,L5
BAYTEKİN MÜHENDİSLİK	Sanding T28	GPS /GLONASS /Galileo / BeiDou /SBAS /QZSS	L1 C/A ,L1C,L2C,L2E,L5 / L1 C/A, L1P , L2 C/A ,L2P,L3 / GİOVE-A , GİOVE-B,E1, E5A ,E5B / L1 C/A ,L5 / WAAS,EGNOS,MSAS,GAGAN/L1,L2C,L5,L6
DOĞA ELEKTRONİK	Stonex S700A	GPS /GLONASS /BeiDou /Galileo /QZSS /NAVIC	L1,L2,L2C,L5/L1,L2,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2,L5,LEX / L5
DOĞA ELEKTRONİK	Stonex S850a	GPS /GLONASS /BeiDou /Galileo /QZSS /NAVIC	L1,L2,L2C,L5/L1,L2,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2,L5,LEX / L5
IFA GRUP MÜHENDİSLİK	Sokkia GCX3	GPS/GLONASS /BeiDou /Galileo /SBAS /QZSS	L1 C/A , L1C,L2P,L2C / L1 C/A , L1P , L2 , L2P / B1,B2 /E1 / L1 ,WAAS,MSAS,EGNOS,GAGAN / L1 C/A ,L1C,L2C
GNSS TEKNİK	CHCNAV İ73 İMU MİNİ	GPS /GLONASS /SBAS / BeiDou /GALİLEO /QZSS	L1,L2,L5/ L1,L2 /L1 / B1,B2,B3 / E1, E5a,E5b / L1,L2,L5
BAYTEKİN MÜHENDİSLİK	Sanding T66	GPS/GLONASS/BEİDOU/Galileo/SBAS	L1 C/A ,L1 , L1C ,L2,L2C,L2E,L5 / L1, L1 C/A ,L1P ,L2, L2 C/A ,L2P ,L3 / B1,B2,B3 / GIOVE-A,GIOVE-B,E1,E2-L1, E5A,E5B,E6-ALTBOC/WAAS,MSAS
GEOTEKNİK MÜHENDİSLİK	South Galaxy G1 Plus	GPS/GLONASS/SBAS/GALİLEO /SBAS	L1C/A, L1C, L2C, L2E, L5 / L1C/A, L1P, L2C/A, L2P, L3 / L1 , L5 / GIOVE-A ve GIOVE-B, E1, E5A, E5B, E5AltBOC, E6 / WAAS, MSAS, EGNOS, GAGAN
BAYTEKİN MÜHENDİSLİK	Gıntec G9	GPS/GLONASS/BeiDou/GALİLEO/SBAS	L1 ,L2E,L2C,L5/ L1 C/A,L1P,L2 ,L2P / B1,B2/ L1 BOC,E5A,E5B,E5 ALTBOC1 /L2 CBOC,E5A,E5B,E5 ALTBOC1 / WAAS,EGNOS,MSAS,GAGAN
BAYTEKİN MÜHENDİSLİK	Pentax G6Tİ	GPS/GLONASS/BeiDou/Galileo /SBAS	L1 ,L2E,L2C,L5 / L1 C/A,L2 , L3 CDMA / B1,B2 / E1,E5A,E5B,E5 ALTBOC / L1 C/A ,L1 SAIF,L2C,L5 / L1 C/A ,L5
SİSTEM A.Ş.	Leica viva GS18T	GPS/GLONASS/BeiDou/Galileo /QZSS	L1,L2,L2C,L5/L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2C,L5,L6
DOĞA ELEKTRONİK	Stonex S900	GPS/GLONASS/BeiDou/Galileo /QZSS	L1,L2,L2C,L5/L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2C,L5,L6
DOĞA ELEKTRONİK	Stonex S980	GPS/GLONASS/BeiDou/Galileo /QZSS	L1,L2,L2C,L5/L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2C,L5,L6
DOĞA ELEKTRONİK	Stonex S990	GPS/GLONASS/BeiDou/Galileo /QZSS	L1,L2,L2C,L5/L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2C,L5,L6
KORDİL MÜHENDİSLİK	Hemispere s321	GPS/GLONASS/GALİLEO/BeiDou/QZSS	L1,L2,L2C,L5/L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2C,L5,L6
BAYTEKİN MÜHENDİSLİK	Gıntec G10	GPS/GLONASS/BeiDou/Galileo /SBAS	L1 C/A ,L1C,L2C,L2E,L5/ L1 C/A ,L1P,L2 C/A,L2P,L3 / B1 ,B2, optinal B3/ E1,E5a,E5b/WAAS,EGNOS,MSAS,GAGAN
BAYTEKİN MÜHENDİSLİK	Pentax G6Nİ	GPS/GLONASS/BeiDou/Galileo /SBAS	L1 C/A,L1C,L2C,L2P,L5/ L1 C/A,L2C,L2P,L3,L5/B1,B2,B3/ E1,E5 ALTBOC,E5a,E5b,E6/L1 C/A,L1C,L2C,L5,L6/L1,L5
GEOMATİK HİZMETLER	Geomax Zenith 35	GPS/GLONASS/BeiDou/GALİLEO/SBAS	L1,L2,L2C,L5 /L1,L2,L3 /B1,B2,B3/E1,E5a,E5b,ALTBOC,E6 /EGNOS,WAAS,MSAS,GAGAN
SATLAB GEOSOLUTIONS	Satlab SL800	GPS/GLONASS/SBAS /GALİLEO/QZSS	L1 C/A, L1C,L2P,L5 /L1,L2 / WAAS,EGNOS,MSAS,GAGAN/E1,E5a,E5b,AltBOC/L1,L2C,L5,L6
GRAFTEK MÜHENDİSLİK	Trimble R12İ	GPS/GLONASS/SBAS/GALİLEO /BeiDou	L1 C/A ,L1C,L2C,L2E,L5 /L1 C/A ,L1P , L2 C/A ,L2P,L3 /L1 C/A ,L5 / E1,E5a,E5B /B1,B2,B3
KAYA HARİTA MÜHENDİSLİK	e-survey E300	GPS/GLONASS/BEİDOU/GALİLEO/QZSS	L1 C/A ,L1P,L1C,L2P,L2C,L5 / G1,G2,P1,P2 / B1,B2,B3 / E1BC , E5A,E5B / L1 C/A ,L5
BAYTEKİN MÜHENDİSLİK	Sanding Venus T3	GPS/GLONASS/BeiDou/Galileo /QZSS	L1 C/A ,L1C, L2C,L2E,L5 / L1 C/A , L2 C/A ,L2P / B1,B2,B3 / GIOVE-A, GIOVE-B,E1 , E5A , E5B / L1 C/A, L5
GNSS TEKNİK	CHCNAV İ70	GPS/GLONASS/SBAS / BeiDou /GALİLEO	L1 C/A ,L2C,L2E,L5 / L1 C/A ,L1P, L2 C/A ,L2P ,L3 / WAAS,EGNOS,MSAS /B1,B2 / E1,E5A,E5B
GRAFTEK MÜHENDİSLİK	Trimble R12	GPS/GLONASS/SBAS/GALİLEO /BeiDou	L1 C/A ,L1C,L2C,L2E,L5 /L1 C/A ,L1P , L2 C/A ,L2P,L3 /L1 C/A ,L5 / E1,E5a,E5B /B1,B2
GRAFTEK MÜHENDİSLİK	Trimble R8s	GPS/GLONASS/SBAS/GALİLEO /BeiDou	L1 C/A ,L1C,L2C,L2E,L5 /L1 C/A ,L1P , L2 C/A ,L2P,L3 /L1 C/A ,L5 / E1,E5a,E5B /B1,B2
ADASTEK MÜHENDİSLİK	ComNav T300 Plus	GPS/GLONASS/BeiDou/Galileo /SBAS	L1,L2,L2C,L5 /L1,L2/B1,B2,B3/E1,E5a,E5b/WAAS,EGNOS,MSAS,GAGAN
GRAFTEK MÜHENDİSLİK	Trimble R2	GPS/GLONASS/SBAS/GALİLEO /BeiDou	L1 C/A ,L1C,L2C,L2E/L1 C/A ,L1P , L2 C/A ,L2P/L1 / E1,E5a,E5B /B1,B2
GRAFTEK MÜHENDİSLİK	Trimble R9s	GPS/GLONASS/SBAS /BeiDou/GALİLEO	L1 C/A ,L2C,L2E,L5 /L1 C/A , L2 C/A ,L3 /L1 C/A ,L5 / B1,B2/ L1 CBOC,E5A,E5B,E5
SİSTEM A.Ş.	Leica Viva GS14	GPS/GLONASS/BeiDou/Galileo /SBAS	L1,L2,L2C/L1,L2/B1,B2/E1,E5b/WAAS,EGNOS,MSAS,GAGAN
SİSTEM A.Ş.	Leica Viva GS14	GPS/GLONASS/BeiDou/Galileo /SBAS	L1,L2,L2C/L1,L2/B1,B2/E1,E5b/WAAS,EGNOS,MSAS,GAGAN
GRAFTEK MÜHENDİSLİK	Trimble SPS855	GPS/GLONASS/SBAS/GALİLEO /BeiDou	L1 ,L2,L2C,L5 /L1, L2 /L1 C/A ,L5 / E1,E5a,E5B /B1,B2
GRAFTEK MÜHENDİSLİK	Trimble TDC150	GPS/GLONASS/SBAS/GALİLEO /BeiDou	L1 C/A,L1P,L2P,L2C /L1 C/A,L2 C/A, / L1 C/A /E1,E5B /B1,B2
GRAFTEK MÜHENDİSLİK	Trimble R1	GPS/GLONASS/SBAS/GALİLEO /BeiDou	L1 / G1 / 4 Kanal/E1/ L1
DOĞA ELEKTRONİK	Stonex S500	GPS/GLONASS/BeiDou/Galileo	L1,L2,L2C,L5/L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6
DOĞA ELEKTRONİK	Stonex S70G	GPS/GLONASS/BeiDou/Galileo	L1,L2,L2C,L5/L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6
GRAFTEK MÜHENDİSLİK	Trimble SPS555	GPS/GLONASS/GALİLEO/BeiDou	L1 C/A ,L2C,L2E,L5 /L1 , L2 C/A,L1 ,L2P /L1 CBOC,E5A,E5B, E5 ALTBOC /B1,B2
GNSS TEKNİK	CHCNAV İ50	GPS/GLONASS/ BeiDou /GALİLEO	L1 C/A ,L2C,L2E,L5 / L1 C/A ,L1P, L2 C/A ,L2P ,L3 /B1,B2 / E1,E5A,E5B
ADASTEK MÜHENDİSLİK	ComNAV G200	GPS/GLONASS/BeiDou/SBAS	L1 C/A ,L2C,L2P /L1 C/A, L1P,L2 C/A , L2P / B1,B2/WAAS,EGNOS,MSAS,GAGAN
ADASTEK MÜHENDİSLİK	ComNav T300	GPS/GLONASS/BeiDou/SBAS	L1 C/A, L1C,L2P,L5 /L1,L2/B1,B2,B3/WAAS,EGNOS,MSAS,GAGAN
GEOMATİK HİZMETLER	Geomax Zenith 25 Pro	GPS/GLONASS/BeiDou/SBAS	L1,L2,L2C/L1,L2/B1,B2/WAAS,EGNOS,MSAS,GAGAN
GNSS TEKNİK	CHCNAV İ90 İMU	GPS/GLONASS/GALİLEO/BeiDou	L1,L2,L5 /L1,L2 / E1,E5a,E5b /B1,B2,B3
GEOMATİCS GROUP	Spectra precision SP20	GPS/GLONASS/ BeiDou /GALİLEO	L1,L2 /L1,L2/ B1,B2 /E1,E5b
GEO TEKNİK	DJİ Matrice 300 RTK	GPS/BeiDou/GLONASS/Galileo	L1,L2 /B1,B2 /L1,L2 / E1,E5a
GNSS TEKNİK	phantom 4 RTK	GPS/BeiDou/GLONASS/Galileo	L1,L2 /B1,B2 /L1,L2 / E1,E5a

Table 1 (continued).

PAKSOY TEKNİK MÜHENDİSLİK	Topcon Hıper SR	GPS/GLONASS/QZSS	L1,L2,L2C/L1,L2,L2C/L1,L2C
LEO MÜHENDİSLİK	NV08C-CSM	GPS/GLONASS/GALİLEO	L1 C/A ,L1C, L2C,L2E,L5 / L1 C/A , L2 C/A ,L2P/E1,E5 ALTBOC,E5a,E5b,E6
GEOMATİCS GROUP	Spectra precision promark800	GPS/GLONASS/GALİLEO	L1 C/A ,L1P,L2C,L2P,L5 / L1 C/A,L1P,L2 C/A,L2P,L3 /E1,E5A,E5B
GEOMATİCS GROUP	Spectra precision promark220	GPS/GLONASS/SBAS	L1 C/A ,L1P,L2C,L2P,L5 / L1 C/A,L1P,L2 C/A,L2P,L3 / L1 C/A,L5
GEOMATİCS GROUP	Spectra precision SP80	GPS/GLONASS/BeiDou	L1 C/A ,L1P,L2C,L2P,L5 / L1 C/A,L1P,L2 C/A,L2P,L3 /B1,B2
IFA GRUP MÜHENDİSLİK	Sokkıa GRX2	GPS/GLONASS/SBAS	L1 CA,L1 , L2 P - code ,L2C/L1,L2 CA,L2P-code/WAAS,EGNOS,MSAS,QZSS
GNSS TEKNİK	CHCNAV LT600	GPS/GLONASS/ BeiDou	L1 C/A ,L2C,L2E,L5 / L1 C/A ,L1P, L2 C/A ,L2P ,L3 /B1,B2
LEO MÜHENDİSLİK	NV08C-RTK-A	GPS/GLONASS/BeiDou	L1 C/A ,L1C, L2C,L2E,L5 / L1 C/A , L2 C/A ,L2P/B1,B2,B3
SATLAB GEOSOLUTIONS	Satlab SL600	GPS/GLONASS/SBAS	L1 C/A, L1C,L2P,L5 /L1,L2 / WAAS,EGNOS,MSAS,GAGAN
GRAFTEK MÜHENDİSLİK	Trimble Geo 7X	GPS/GLONASS/SBAS	L1 C/A ,L2C,L2E / L1 C/A,L1P,L2 C/A / L1 C/A
GRAFTEK MÜHENDİSLİK	Trimble SPS461	GPS/SBAS	L1 C/A,L1-L2 / 4 Kanal

Figure 1. Number of Satellite systems and signals used (The number of signals it sees, the number of satellites it has seen)

Using Table 1, a ranking was made from the device that sees the least satellite system and signal to the maximum and a visual graph was created (Figure 1). As a result, it has become easier to examine the device that receives the most signals and sees the most satellite systems via the corresponding table. Accordingly, it has been seen that the most ideal device for our country is the Kolida K58 Pus device, which can work with systems such as GPS /GLONASS /SBAS / GALILEO / QZSS / BEIDOU and receive signals from many satellites of these systems (Figure 1).

Author contributions

The authors contributed equally.

Conflicts of interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

This study complies with the rules of research and publication ethics.

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