RESEARCH ARTICLE

Implementation of Serverless Cloud GIS Platform for Land Valuation

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ABSTRACT
Cloud computing enables performing computations and analysis tasks and sharing services in web-based computer centres instead of local desktop systems. One of the most used areas of cloud computing is Geographic Information Systems (GIS) applications. Although Desktop GIS products are still used in the community frequently, Web GIS and Cloud GIS applications have drawn attention and have become more efficient for users. In this study, a serverless Cloud GIS framework is implemented for land valuation platform. In order to store, analyse, and share geospatial data, Aurora Serverless PostgreSQL database is created on Amazon Web Services (AWS). While adopting Aurora Serverless PostgreSQL as database management system, a simple point in polygon analysis conducted to compare the performances with Amazon RDS instance. Results showed that serverless database responded to the query faster and scaled up during high workload to decrease latency. Hence, parcel vector data, which conveys ownership information and land values attributes, is shared directly from the PostGIS database as vector tiles. Besides S3 and AWS Lambda services are used for storing and disseminating raster-based land value map tiles. To visualize all shared data and maps through a web browser, open source web mapping library Mapbox GL JS is used.

KEYWORDS
Serverless Cloud Computing; Cloud GIS; open source GIS; real estate valuation; value map

1. Introduction

Rapidly growing existence of geospatial data requires different approaches for storing and sharing big data bulks. With the development of cloud computing systems, it is possible to store, process, and share large data volumes on virtual machines through the web. Cloud computing has changed the way people look into the Information Technologies (IT) infrastructure since it has many advantages in comparison with conventional system architectures.

Real estate valuation is an estimation process of property values with technical knowledge and it depends on many internal and external factors. Evaluating land parcels in large areas like city or district scale requires numerous analysis, data process, and long operation time. In order to carry out this procedure with scientific methods objectively, Geographic Information Systems (GIS) can facilitate to store, view, analyse and share real estate data and maps.

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GIS cloud framework provides high performance of data storage and computing capabilities, in addition, it decreases requirements of hardware and IT staff. Furthermore, platform and service deployment models on the cloud systems eliminates instalment and maintenance steps on the user side.

There are many research papers about cloud computing and GIS integration since the beginning of the last decade. Yang and Wu (2010) summarized the cloud computing definitions in the literature and discussed the cloud computing technology with its properties and implementation stages. They also covered decision support systems, geospatial applications, and spatial data storage procedures on the cloud. Schäffer, Baranski, and Foerster (2010) created a cloud based Spatial Data Infrastructure (SDI) and generated a stress test to observe performance of the cloud in terms of scalability and availability. OGC White Paper examined cloud computing evolution from the geospatial point of view in order to establish a reference model for standards. In this draft, they summarized adoption of cloud computing in the geospatial community, its advantages and disadvantages for users and corporates (McKee, Reed, and Ramage 2011). Diasse and Kone (2011) integrated GIS and private cloud to develop secure, effective, and performant geospatial cloud framework. Agarwal and Prasad (2012) developed an open architecture-based cloud solution for geospatial applications on Microsoft Azure platform. They summarized the knowledge and insights about the entire process, from storage, computing, provision, and deployment of the cloud system. Huang et al. (2013) analysed different properties and abilities of three open source cloud vendors and generated benchmark tests for computing, networking, imaging performances with geoscience applications. Aly and Labib (2013) created a GIS based earthquakes prediction and emergency management system on Microsoft Azure Cloud. They also compared capabilities and performances of both cloud and local systems. Lněnička and Komárková (2013) summarized cloud computing and Cloud GIS concepts and carried out cloud-based tests to measure response times and to detect performance problems of web-based GIS platforms in Czech Republic. They also determined the average peak load of the platforms by testing them in different times of the day. Evangelidis et al. (2014) proposed a cloud-based framework for web applications with open geospatial standards. Li et al. (2015) provided a big geodata analytics platform on the cloud with MapReduce and Service Oriented Architecture (SOA). They highlighted the implementation barriers and solutions with the proposed concept on a big climate data processing application. Li et al. (2017) proposed Model as a Service (MaaS) which offer a comprehensive geoscience modelling service from establishing infrastructure and system configurations to processing models and interpreting the results on the Eucalyptus open source cloud. Yang et al. (2017) discussed the integration of Big Data and cloud computing in the geospatial domain and stated the findings and advantages of this combination. Helmi, Farhan, and Nasr (2018) proposed a model consisting of hybrid cloud system and GIS for health solutions in Egypt. Cai and Jiang (2019) proposed a geospatial data management and sharing platform for smart cities on the cloud. Slocum and Tang (2020) developed the GeoWebSwarm, a container-based Cloud GIS platform, to enable high performance computing for Web GIS applications. Tripathi, Agrawal, and Gupta (2020) reviewed Spatial Data Infrastructure (SDI) and National SDI (NSDI) concepts from a cloud-based service-oriented architecture perspective to highlight the aspects of spatial data management, interoperability, security, and reliability.

Improvements in cloud computing domain have increased its use in IT solutions (Eurostat Statistics Explained 2018; Kim 2020). One of the promising development of the cloud computing is serverless architecture. Serverless is a computing model where system operations are fully managed by service provider (Serverless.com 2021). Using serverless computing in geospatial applications can solve performance and pricing issues that can boost dissemination of spatial data. Bebortta et al. (2020) discussed the potential of integrating serverless computing into geospatial applications and proposed a framework to handle geospatial big data in terms of processing time, computational cost, and scalability. They performed two different case studies using overlay, heatmap, and clustering analyses in desktop computing environment to emphasize the need for transition to serverless architecture. Addresscloud company have developed serverless geospatial solutions for storing and disseminating vector and raster data using Amazon Web Services (AWS) (Holderness 2019). DeMuth (2020) implemented a serverless web application on AWS using ArcGIS API for JavaScript together with Amazon Simple Storage Service (S3) and Athena for spatial data analysis.

Infrastructure setup, maintenance, and performance configuration needs are some of the drawbacks of running servers. Providing rapid, secure, highly available, and cost-efficient services in real estate management, serverless geospatial applications can be utilized. The objective of this research is to implement serverless architecture for GIS based land valuation platform on AWS. Section 2 covers Cloud Computing, AWS, and Cloud GIS notions with their features and benefits. Section 3 discusses the comparison of server and serverless database architectures in performance, execution time, and cost aspects. It also explains the utilization of the open source GIS tools on serverless cloud computing for land valuation platform. The last section discusses the results of the work as well as the superiority of the scalable, performant, cost optimized serverless framework with its potential and concludes the research.

2. Cloud Computing

According to the National Institute of Standards and Technology (NIST), cloud computing is a model that provides ubiquitous, proper, on-demand network access to a shared pool of adjustable computing supplies like networks, servers, storage, applications, and services. It does not require much exertion or involvement on client-side when system configuration and deployment (Mell and Grance 2011). Although the emergence of cloud computing system dates back to 1960s, 'cloud' term is first introduced in 2006 with the efforts of technology companies like Google, Amazon, Microsoft, and IBM (Regalado 2011). It gained popularity with Amazon's Elastic Compute Cloud (EC2) product all over the world.

Cloud computing systems have four deployment types: Private, community, public, and hybrid (Bhat, Shah, and Ahmad 2011). Private deployment model provides on or off the premises special cloud infrastructure to users like individual organizations with numerous employees. Community model supply cloud infrastructure for a particular group which has common objectives like a business sector, aim, or need. Public model is supplied for open utilization of cloud infrastructure on premises of the provider. Hybrid cloud can be regarded as combination of other deployment models, yet it has individual features for advanced solutions (Mell and Grance 2011).

Cloud computing technology comprises five major features: On-demand service configuration, wide network access, resource pooling, rapid elasticity, and pay as you go characteristics. On-demand service configuration feature enables providing computing utilities so that users can manage preferences like server capabilities and storage as intended. Wide network access feature ensures that thin or thick client platforms can reach to the services with standard protocols. Resource pooling characteristic of cloud systems provide dynamically enabled, location independent virtual and physical computing supplies for multiple users with multi-tenant model. Rapid elasticity feature offers flexible, scalable, on demand, automated provision of services at any time. Lastly, pay as you go capability makes enable monitoring, managing, optimizing, and reporting the resources using metering functionality (Helmi, Farhan, and Nasr 2018).

There are three main service forms in cloud computing systems: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). SaaS provides ability to use applications on a networks of computing equipment. Users do not need to handle servers, networks, operating systems, storage, implementation, or maintenance. Moreover, organizations can use information systems or applications on the cloud instead of buying software, hardware and employing IT workers (Alfaqih and Hassan 2016). PaaS supply deployment of frameworks or applications for software development which requested by consumers. Cloud infrastructure in PaaS model does not managed or controlled by users, however they have authority over frameworks and applications. IaaS deployment model provides basic computing capabilities like computing, storage, network, and processing. Users can also deploy an operating system and applications which they can manage and control on the cloud infrastructure (Lněnička and Komárková 2013). We can consider the AWS EC2, GCP Compute Engine, or Microsoft Azure Virtual Machines as IaaS; ArcGIS Server, GeoServer, MapServer, or QGIS Server as PaaS; ArcGIS Online, Mapbox, or CartoDB as SaaS examples (Mete 2019).

Except from three main service models, there is Everything as a Service (XaaS) which means all possible services and applications that can be provided over internet on demand (Duan et al. 2015). Among these, one of the most used models is Function as a Service (FaaS). It is an alternative for deploying applications in the cloud. FaaS runs the function on demand so that users can execute backend code without provisioning or maintaining servers. FaaS is generally used for building microservices, processing HTTP requests, message queue, or task scheduling purposes (Goebelbecker 2020). AWS Lambda, Google Cloud Functions, Microsoft Azure Functions, IBM/Apache's OpenWhisk, and Oracle Cloud Fn are some of the FaaS examples in the cloud market. FaaS is the core concept of the serverless computing architecture which is an execution model where infrastructure management operations like server or cluster provisioning, capacity provisioning, and maintenance are handled by the cloud provider. Serverless architecture enables building and running services and applications without thinking about servers. On the other hand, users only pay when a serverless application is used, which means that cloud provider does not charge you any fees other than data storage when the system is not operating.

Among leading technology companies, there are prominent cloud computing service providers like AWS, Google Cloud Platform (GCP), Microsoft Azure, IBM Cloud, Oracle Cloud, Digital Ocean, Rackspace. In this paper AWS is adopted as cloud computing platform, since it has many service alternatives, reasonable service costs, data centres in many locations, and highly available services.

2.1. *Amazon Web Services*

AWS is one of the major public cloud service providers in terms of functionality, availability, service variety, sizing, and cost (Dillmann 2016). There are many companies and institutions that cooperate with AWS like Airbnb, Autodesk, BP, Canon, Deloitte, Duolingo, Foursquare, Here, Hitachi, HTC, McDonalds, Netflix, Philips, Siemens, and

Xiaomi. As a third-party cloud provider, AWS has hundreds of services which include computing, storage, networking, database, analytics, application services, deployment, and management solutions for its business partners (Amazon Web Services 2020a). In this paper, the most known and used AWS services, EC2, S3, and RDS are explained.

2.1.1. Elastic Compute Cloud (EC2)

EC2 is a web service that offers secure, resizable compute capacity and scalable deployment of applications in the cloud. EC2 service can be regarded as IaaS since AWS takes the responsibility of server, storage, networking, and virtualization itself; on the other hand, users are responsible for handling operating system, data applications, middleware and runtime (Shao et al. 2012). Users can launch an Amazon Machine Image (AMI) to create a ready-to-use virtual machine, which is called 'instance'. AMI consist of Windows or Linux operating system, software and applications. Management and configuration of the instances can be controlled over management panel called 'console'.

2.1.2. Simple Storage Service (S3)

AWS S3 is an online object storage service that provides security, performance, scalability, and data availability on the cloud environment. It stores data with high durability (99.99%) for numerous applications to serve corporations and firms in many countries (Amazon Web Services 2020b). Objects are redundantly stored on several machines across multiple data centres in an Amazon region. To manage objects located in the S3 bucket and perform basic operations (copy, publish etc.), console or command line interface can be used.

2.1.3. Relational Database Service (RDS)

Amazon RDS provides relational databases in the cloud through web services. It is designed to ease creation, control, and scaling processes of the databases. According to users' needs, it supplies scalable, resizable database with memory, Input/Output (I/O) bottleneck, or performance optimization. RDS also enables automatically patching, back up and incremental recovery (Hubbard 2019). As a SaaS, RDS offers well-known database systems like Amazon Aurora, MariaDB, MySQL, Oracle Database, PostgreSQL, and SQL Server. Moreover, users can migrate their existing databases to RDS with AWS Database Migration Service quickly and securely.

Amazon RDS also offers serverless database with Amazon Aurora for both MySQL and PostgreSQL. Amazon Aurora Serverless can automatically start up, shut down, scale up, and scale down based on the application workload. By setting the memory and Aurora Capacity Units (ACU) for processing, there is no need to provision database server. When number of connections and CPU utilization are increased, Aurora Serverless scales up in response to requests with very low latency in the "warm" state. Inversely, it scales to zero when there is no connection for some configurable time (Figure 1). Warm pool of resources means that the database cluster is being actively used during the query and is ready to response to the service requests. In the "cold" state of the system, there is no charge except for data storage.

Scalability and pay-per-use features of the Aurora Serverless result in significant cost savings when compared with RDS on demand instances. For example, hourly price of db.t3.medium (4 GiB memory) instance class with two availability zones is $ 0.164, while Aurora Serverless with 2 ACU (4 GiB memory) costs $ 0.120. On the

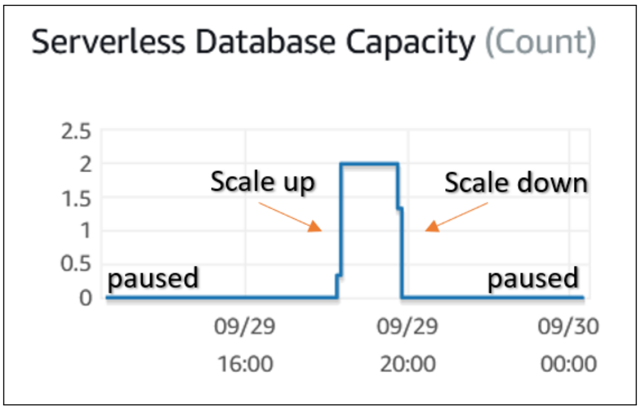

Figure 1. Aurora Serverless Database scalability during different system workloads.

other hand, db.r5.large (16 GiB) instance costs $ 0.580 per hour, Aurora Serverless with 8 ACU costs $ 0.480 per hour. Hence, using Aurora Serverless database instead of RDS instance will reduce the costs dramatically in the long run. It is possible to create usage scenarios and to estimate monthly bills of the cloud services using online AWS Pricing Calculator tool (Amazon Web Services 2021).

2.2. *Cloud GIS*

Cloud GIS notion has arisen as the compound of GIS and cloud computing. Beyond GIS capabilities, it enables highly available, scalable, secure, and cost-friendly data storage, software, and contents. Using GIS on the cloud environment, users can reach data, maps, and geoprocessing services easily (Peng and Wang 2014).

Cloud GIS has many benefits like supplying implementation environment, providing hardware and software resources, minimizing IT professionals and support needs, decreasing costs, enabling advanced data management, and offering location-free resource pooling.

With the help of IaaS service model, it is possible to create GIS infrastructure on the cloud systems. Implementation of Cloud GIS provides geospatial data management, analysis, and storage. It also enables web services and application hosting to access, publish, and consume the data easily (Diasse and Kone 2011).

Cloud computing systems provides hardware and software for enabling computing resources, software, and applications to build a complete geospatial environment on the cloud. Users can create instances with intended specifications according to the needs of computing power, performance and budget. Furthermore, operating system, GIS software, applications and tools can be installed using cloud machine images simply.

Implementation of GIS framework increases efficiency and performance, while reduces costs. Users are in charge of only the services they consume thanks to the pay as you go characteristic of the Cloud GIS. Scalability feature makes possible to increase or decrease the compute, storage, and network capacities as intended and it facilitate geospatial data manipulation.

Cloud GIS provides resource pooling for processing, networking, and storage requests using multi-tenant model. With the location independent pooling, resources are served to multiple clients across centralized cloud infrastructure. Those resources can be provisioned and scaled with the demand of the users (Bhat, Shah, and Ahmad 2011).

Table 1. Database system specifications.

	CPU	Memory	Storage
RDS Instance	1 Core 1 vCPU (3.3 GHz)	1 GB	20 GiB
Aurora Serverless	Scalable	2 ACU (4 GB) – 384 ACU (786 GB)	10 GiB – 64 TB

3. Methods

3.1. *Serverless Cloud GIS*

Growth in the geospatial domain is proportional to the increase in number of users and geospatial data volume (Geospatial Media and Communication 2018). Providing better GIS services requires more efficient and innovative approaches. Serverless computing which regarded as new generation cloud architecture has started to take place in GIS applications. In order to compare the traditional Cloud GIS and Serverless GIS models, AWS RDS PostgreSQL (11.5) and AWS Aurora Serverless PostgreSQL (10.7) databases were implemented on the cloud for geospatial data storage and processing (Table 1). To compare the performance of the two database system architectures, a simple point in polygon analysis generated within PostGIS. Point in polygon algorithm can be used for many location-based applications. For example, a real estate agent can use this analysis in order to know how many properties they have in their area of responsibility for efficient asset management.

A set of sample point data were created for performance testing around districts of Istanbul city. After loading the same point data to the databases, following SQL query was executed to draw a rectangular box with bounding coordinates using PostGIS's ST_MakeEnvelope() function.

```
SELECT id, name, ST_Contains(ST_MakeEnvelope(29.0432, 41.0838,
29.0503, 41.0876, 4326),geom)
FROM point
WHERE name = 'istanbul';
```

The query was responded in 1 second 9 millisecond on RDS, while 371 milliseconds on Aurora Serverless database (Figure 2). It shows that serverless database runs 2.72 times faster than RDS. When AWS announced the Serverless Aurora PostgreSQL, they asserted a performance increase up to three times (Amazon Web Services 2017). The results are consistent with the claimed performance increase.

After executing the query in both RDS and Aurora Serverless databases, performance metrics like CPU utilization, I/O Operations Per Second (IOPS), latency were reported using AWS CloudWatch (Figure 3). The test results showed that serverless database used less CPU (around 3%) in comparison with RDS (around 15%). On the other hand, Serverless database had lower IOPS and latency, which means that Serverless database had scaled up while the query execution and responded quickly with very low latency (1-2 milliseconds).

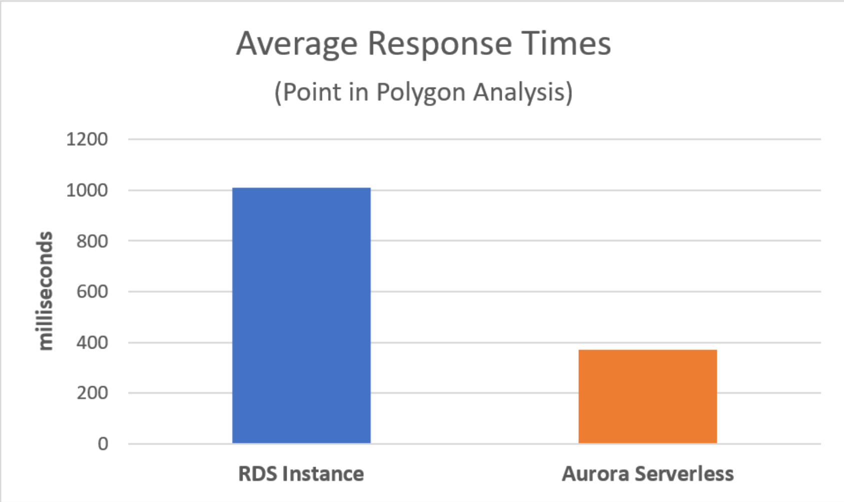

Figure 2. Average response times of the two databases.

3.2. *Case study: Serverless Cloud GIS platform for land valuation*

Land valuation is a complex procedure since there are numerous factors that affect the value. To assess land values objectively and analysing the effects of internal and external factors is getting easier thanks to the GIS. It is also possible to share those real estate data and maps with the users through Web GIS and Cloud GIS technologies. Moreover, mass land valuation process requires big data storage, processing, and sharing. Serverless Cloud GIS architecture is capable of doing all those in a cost-effective way with high performance, security, and availability. In this study, a serverless Cloud GIS framework was created for producing land value map of Istanbul city with nominal mass valuation method. Produced maps and data were stored and published using open source geospatial applications on AWS.

3.2.1. Description of the study area: City of Istanbul, Turkey

Turkey's most cosmopolitan city of Istanbul is selected as the study area (Figure 4). Located in the Marmara Region, the city of Istanbul ties together the European and Asian continents and acts as an important connection point for land, air and sea transportation. Having approximately sixteen million population and 5461 km^2 area, Istanbul is a centre of attraction due to its important opportunities (Governorship of Istanbul 2020). The city grows and develops day by day, and its population is increasing at the same rate. The demand for real estate is also quite high and those reasons cause high sales and rental values in properties. Therefore, a cloud-based real estate management platform is created to provide data driven analytics for Istanbul city.

3.2.2. Land valuation

Land valuation is the process of examining the properties of lands as a whole considering the economic developments and estimating the unit value under current market conditions (Yomralioglu 1993). There are several techniques for real estate valuation, however they can be divided into two general groups: Classical methods and stochastic methods (Yomralioglu 2019). Income Capitalization, Sales and Comparison, and

Figure 3. Amazon CloudWatch database performance metrics.

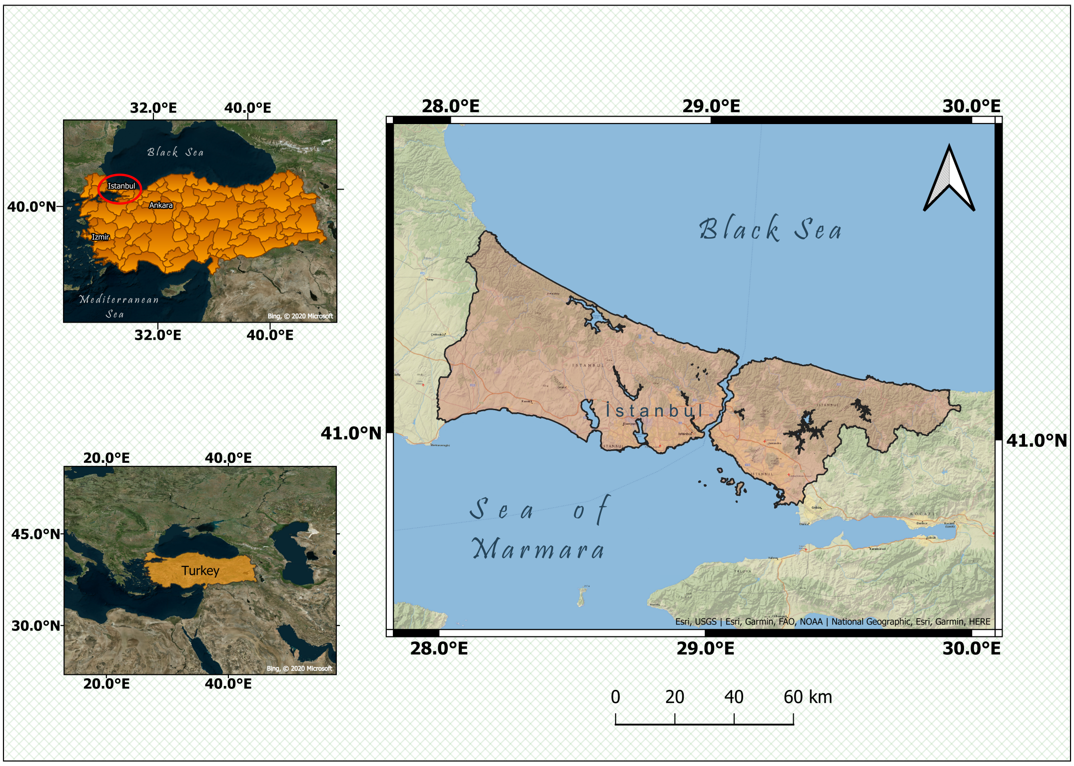

Figure 4. Description of the study area: Istanbul city.

Replacement Cost methods are known as classical methods; on the other hand, Nominal Valuation, Regression, Hedonic Pricing, Mass Valuation methods are stochastic methods. Stochastic methods are based on statistical models that requires analysis by computers since these methods are applied for a large number of real estate. In this paper, GIS based nominal land values of Istanbul city which were created by Mete (2019) are used to store, view and publish real estate data and land value maps with the help of Cloud GIS and Web GIS technologies.

Nominal valuation is a method that provides weighted parametric values of the criteria which affect land values (Yomralioglu 1993; Mete and Yomralioglu 2019). The distribution of values between lands can be seen easily by using Nominal Valuation Method. It establishes a scientific approach since the criteria are formulated and the values are created independent from market prices objectively. Nominal Valuation Method provides interpretation of value distributions relative to each other, yet they can be converted to real market values easily (Yomralioglu, Nisanci, and Yildirim 2004).

3.2.3. GIS solutions in land valuation

It is very difficult to limit factors which affect real estate values. Evaluating those numerous factors and obtaining unit value of the real estate requires dozens of analyses and procedures. To deal with this complex process, GIS can be utilized through its easy data manipulation, advanced automation, and robust spatial analysis capabilities. Comparison with the classical valuation methods, GIS-based stochastic methods facilitate mass valuation of big areas in a short time, and enable displaying, creating, storing, analysing, and sharing real estate data and maps. Using Web GIS applications, it is possible to create real-time maps and display land values on the web browser dynamically.

3.2.4. Building a serverless open source geospatial stack on the Cloud

In this study, open source geospatial tools were adopted on the serverless cloud in order to share land valuation data and maps with high performance. In the serverless cloud model, there is no need to create any computing instance like EC2 for provisioning geospatial applications. Therefore, all infrastructure management, software installations/updates, and maintenance operations are handled by the cloud provider.

To build a serverless open source geospatial framework on AWS, Aurora Serverless PostgreSQL database was installed with PostGIS extension to enable spatial data storage, analysis, and dissemination. All required vector and raster datasets like district and neighbourhood boundaries, parcel boundaries, real estate valuation data loaded into the database. It is possible to access to Aurora Serverless PostgreSQL database using RDS Query Editor, SSH Tunnel in the same Virtual Private Cloud (VPC), or VPN connection.

After setting up the database, parcel boundaries data was published in Mapbox Vector Tiles (MVT) format in order to increase efficiency while displaying big amount of vector data on the web. Vector tiles was dynamically served directly from the database by using PostGIS ST_AsMVTGeom() and ST_AsMVT() functions. This new architecture does not require any middleware rendering program like GeoServer, MapServer, or Mapnik, instead it uses a lightweight tile service to convert map requests into SQL query (Ramsey 2019). When a tile request comes from the web browser, AWS API Gateway transfers this Application Programming Interface (API) call to AWS Lambda which controls the requested tile location and information. Then it calls this specified tile from the database through Data API which provides a secure HTTP endpoint to run SQL statements. Thus, the requested tile is sent back to the browser (Figure 5).

For sharing land value map as a web service, raster tiles were created in MBTiles format in QGIS with built in "Generate XYZ Tiles (MBTiles)" tool and were uploaded on S3 bucket. By configuring object settings and policies (public access, CORS), raster tiles were shared serverless through S3 and Lambda services. In order to increase the delivery speed of the data, AWS CloudFront Content Delivery Network (CDN) was used to enable edge caching (Figure 6). Pre-generated raster tiles can be reached through XYZ tile protocol which is a URL that includes zoom level and x/y coordinates (https://mekansalveri.s3.amazonaws.com/tile/z/x/y.png).

All the published cloud-based geospatial data can be accessed by tile services using desktop GIS software (QGIS, ArcGIS etc.), or web browsers with the help of web mapping libraries. There are many JavaScript web mapping libraries like ArcGIS API for JavaScript, Leaflet, OpenLayers, Mapbox GL JS for displaying maps on the web browser. In this paper, Mapbox GL JS open source web mapping library was used, since it has well design, readable source code, functional plugins, and detailed documentation. It uses Web Graphics Library (WebGL) for map rendering, and works with desktop and mobile platforms seamlessly. Using Mapbox GL JS library, real estate valuation data which published from Cloud GIS environment is presented on the web (Figure 7).

Users can display nominal valuation map and can find the current value of any parcel in the Istanbul city by clicking on the parcel or searching the attributes (Figure 8). On the other hand, satellite images, topographic maps, and vector maps can be displayed as a basemap by using XYZ tile service and OGC Web Services (OWS). It is also

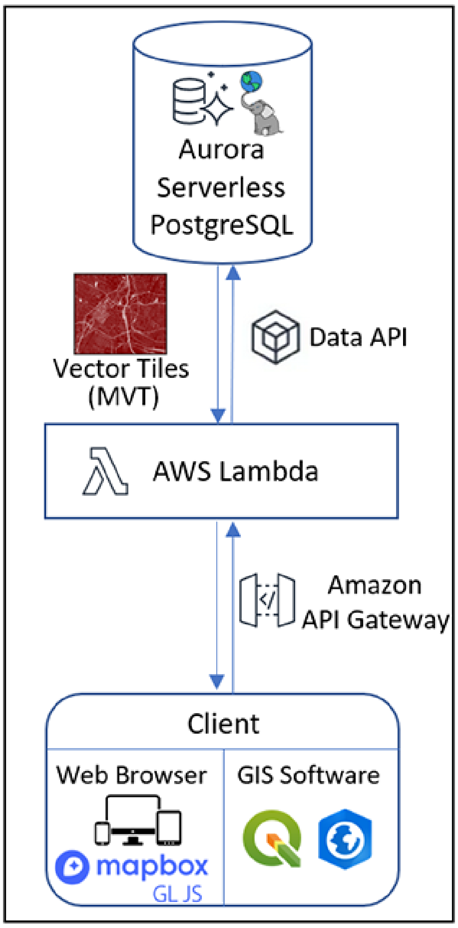

Figure 5. Workflow of backend system for serverless vector tile sharing.

possible to measure distances on the map, searching address, and geolocating users to show land values of the located neighbourhood. Within the scope of the study, it is aimed to provide an important reference to value-based applications through this real estate management platform by providing land value map and social and environmental data which express urban life indicators.

4. Discussion and conclusion

With the continuously developing computing technologies, enterprises or individual users can find improved solutions to the growing needs and problems. Cloud computing systems offer significant opportunities by removing borders in storage, computing, and networking fields. Cloud GIS infrastructure has changed the approach towards geospatial systems in terms of data storage, data visualization, geoprocessing, and data sharing. Using those improvements in GIS-based decision support systems can facilitate to build scalable, dynamic, secure, and robust geospatial frameworks on the web.

There are various ways of disseminating vector and raster data on the web. In this study, it was intended to provide 'state of the art' methods for storing, visualizing, and sharing geospatial data. Utilizing serverless architecture, it has become possible

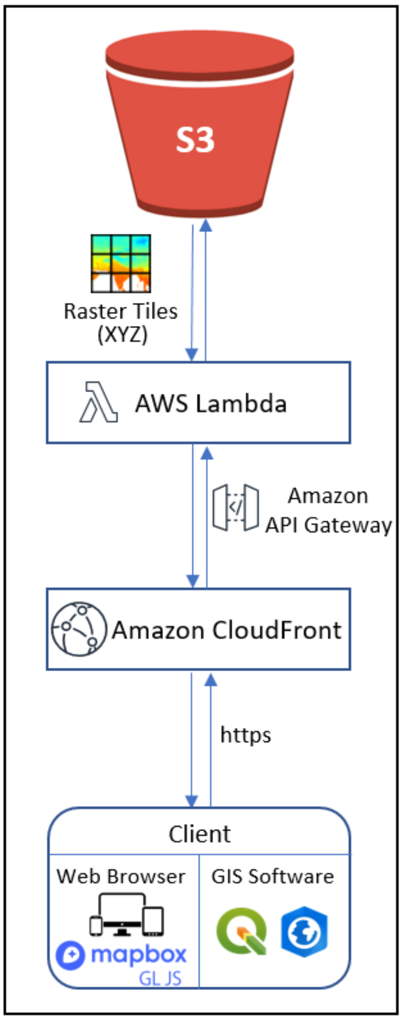

Figure 6. Workflow of backend system for serverless raster tile sharing.

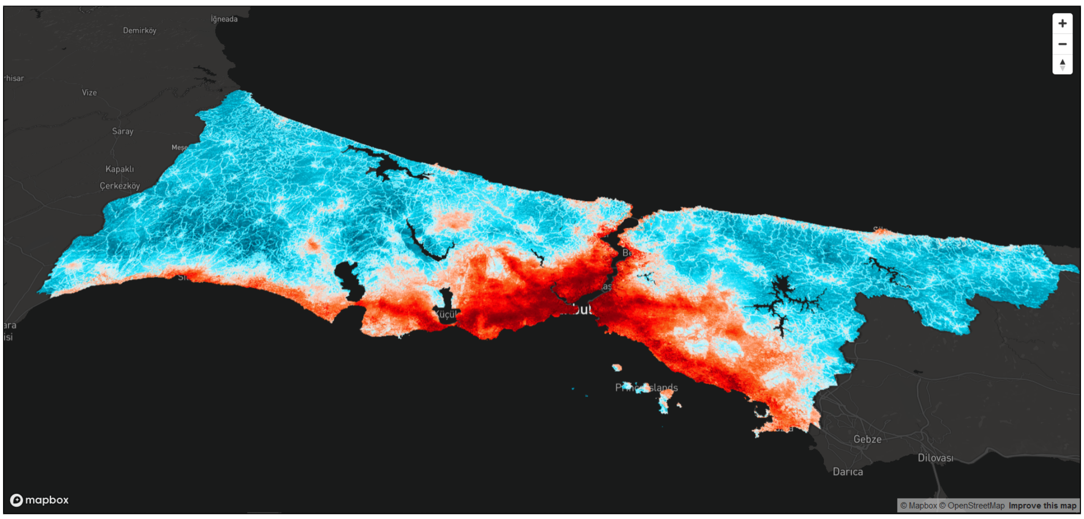

Figure 7. Nominal land value map of Istanbul city.

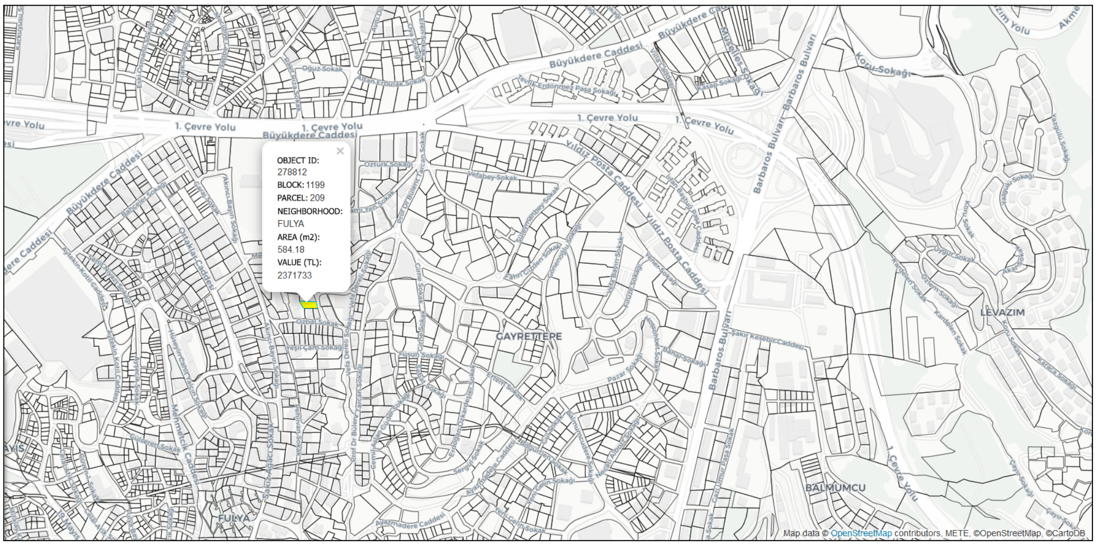

Figure 8. Visualizing and querying land parcels in the web browser using Mapbox GL JS.

to achieve high performance, high availability, high durability with a cost-effective solution on the cloud. Serverless model removes the installation, maintenance, and provision of instances; therefore, users can have more time to produce applications without thinking the infrastructure. Moreover, the scalable feature of the serverless architecture not only decreases the latency by scaling up, but also reduces the cost by pausing when there is no request to the system.

Geospatial data and its size are growing exponentially, and more users are getting involved with GIS-based solutions and platforms in a daily routine. All those reasons require effective solutions and appropriate methods for handling the systems. The needs and goals of the GIS applications are suitable for implementing serverless computing model. In this study, open source GIS-based serverless cloud framework was created for mass land valuation on AWS. Serverless Aurora PostgreSQL database showed effective, robust performance on the spatial analysis test. Therefore, we adopted it for storing and dynamically sharing the vector data including land parcels. In order to store and disseminate the raster-based land value map, Serverless AWS S3 and Lambda services were used. In addition, real estate management portal was created by using open source Mapbox GL JS mapping library for users who want to query their properties to display predicted values and other attribute data on the web browser.

Recent studies generally have been focusing on Web GIS, server based web services (OWS), and IaaS/PaaS based Cloud GIS applications (Blower 2010; Mahmoud, Hegazy, and El-Dien 2013; Fan et al. 2013). Transition from traditional spatial data handling to cloud based services taking place very slowly in many organizations (Altaweel 2020). Even SaaS based applications are rarely encountered. However, popular technological developments like big data, Internet of Thing (IoT), Artificial Intelligence (AI) enforce GIS industry to search for new approaches at the intersection. This study provides scalable, performant, cost optimized serverless computing framework for GIS-based land valuation platform with open source software.

Objective valuation of lands and sharing up-to-date market values with owners are crucial matters that help regulate the market by preventing speculation. By creating a serverless cloud based open source geospatial software stack, it facilitated to store, view, analyse and share real estate data and maps on the web.

As a future work, it will be beneficial to use this framework as a reference in value-related applications such as taxation and urban regeneration with the implementation of an interactive valuation platform where GIS-based mass real estate valuation including housing valuation. This approach will require a 3D web mapping library (Mete, Guler, and Yomralioglu 2018) to visualize the land together with the buildings on the web. On the other hand, Cloud Optimized GeoTIFFs (COGs) data format can be used with AWS Lambda service for large raster data to provide serverless, efficient data access. Utilizing more FaaS based geospatial applications in the cloud system will bring about automation of the GIS workflows. Since AWS Lambda has native support for many programming languages (Java, Python, Go, Node.js etc.), there is a huge potential for combining GIS and serverless computing on the cloud.

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