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Valuation and Volatility of Virtual Properties in Metaverse: Exploring New Market Opportunities and Speculative Dynamics Based on Decentraland

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***Abstract*— Existing reality has been repeatedly subjected to multifaceted and multidimensional analyses. However, alongside it, a virtual reality exists, populated with virtual art, objects in games, cyber-pets, and virtual properties, collectively worth billions of real dollars. This virtual reality is associated with the concept of the 'metaverse' (a term derived from 'meta' and 'universe'), signifying a space that facilitates life in a virtual world. This space has a quantifiable value and is traded on specially designed platforms. The study focuses on the largest of these platforms, Decentraland, where users can purchase virtual properties using a cryptocurrency called MANA. Based on an analysis of 207 property transactions, the study examines whether these properties can be appraised using typical approaches applicable to "real" properties. It explores the relationship between spatial attributes, property price, and price volatility over time, calculating correlation coefficients for this purpose. Additionally, the study investigates the number of property sales, including multiple sales, and the proportion of properties with ITEMs on them, determining the correlation coefficients between price and parcel attributes. This study is the first to accomplish what researchers in the real estate market have long been doing. The results distinctly show that the virtual real estate market is governed by different factors compared to the traditional market, with property price and location remaining as two crucial aspects in the decision-making process for purchasing a property.**

Keywords*— *Metaverse, virtual real estate, Decentraland, parcel, real estate, real estate valuation, virtual reality, blockchain, NFT

I. INTRODUCTION

The development of civilization, along with the technological advances that accompany it, despite their drawbacks, brings many opportunities. These include easier access to information, improved communication and transportation, increased productivity, and the advancement of information technology [8]. It is the latter that has enable the creation of what is known as virtual reality [34]. The relationship between virtuality and reality has been a subject of consideration since ancient times, notably in the ideas of the Greek philosopher Plato and his concept of good and bad illusions. The motif of transitioning to another, parallel space-time is also frequently explored in film and literature, often using a mirror, window, or door as a portal [50]. However, what was once associated with science fiction has now become a reality. Today, 'the door' to the virtual world is the computer [67]. It is a sign of our times that we live our lives equally in the real and virtual worlds, where processes and events in the virtual dimension increasingly replace or supplement the real ones [30]. Examples include meeting other others (other virtual world users), purchasing digital goods and products, and even real estate [17]. It is predicted that by 2026, a quarter of the population will spend at least one hour a day in the metaverse, engaging mainly in education, health care, marketing, and other services [21]. Virtual reality (VR) is a computer-generated three-dimensional environment that allows users to move and interact within it. An alternate term for VR, derived from English, is 'metaverse,' a combination of 'meta' (beyond) and 'verse' (from 'universe' - space) [26]. The Metaverse can thus be defined as an environment where users worldwide can connect, establish relationships, and exchange goods; in other words, it is an alternative, computer-generated world where people can share and interact globally. With reference to the above definitions, the metaverse's characteristics include sustainability, synchronicity, openness to all with no user limit, a fully functioning economy with property rights, a link between the virtual and real worlds, interoperability, and content created collaboratively [9].

This paper analyses the real estate market of the Decentraland platform. This focus is due to the platform's high popularity and the easy accessibility of data, such as transaction histories. Furthermore, Decentraland's design ensures its status as a truly decentralized platform, independent

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of the influence of large-scale investors [12][36]. Decentraland operates on the Ethereum blockchain, using MANA as its native currency, which serves as both a transactional utility within the marketplace and a stable currency that aligns with real-world exchange rates. This dual functionality distinguishes MANA from tokens on other platforms, which may lack such versatility, thus providing Decentraland with a stable economic framework for virtual real estate valuation and transactions. However, the rapid expansion of virtual real estate platforms like Decentraland and others presents certain risks, such as market saturation due to the potential oversupply of virtual properties. This oversupply, combined with the speculative appeal of virtual assets, may lead to increased volatility and impact long-term valuations. Recognizing these dynamics, this study analyses the Decentraland platform's real estate market to understand the valuation mechanisms and volatility trends that differentiate virtual from traditional property markets.

Metaverse platforms are primarily built on blockchain technology, which has seen significant development in recent years [48]. Blockchain is a method of data storage that forms a one-way (chronological) chain of records, known as blocks. The technology has emerged in response to the anticipated increase in user-generated data within the metaverse space [55]. It facilitates transactions directly between users — peer-to-peer — without the need for intermediaries [18]. Notable features characterizing blockchain technology include [43]:

- Immutability: Data entered cannot be modified;
- Decentralization: Every user has access to the data;
- Consensus-based: A mechanism that is resistant to fraud attempts, increasing user confidence;
- Transparency: The entire chain is publicly available, providing an opportunity for verification;
- Internationality: The system is open to everyone;
- Anonymity: User data is not disclosed.

II. METAVERSE

The metaverse is defined as "*a virtual reality setting where users may engage in sustained and immersive interactions with other users and digital information*" [6]. It is a loosely defined term referring to three-dimensional virtual worlds where users, represented by avatars, interact [15][44]. The term 'Metaverse' originated in the 1992 science fiction novel 'Snow Crash', as a portmanteau of 'meta' and 'universe' [10][66]. As a relatively new phenomenon, it has not been extensively studied by researchers. Existing studies include applications of accounting and auditing in virtual worlds [5]. They necessitate the creation of new digital tools and call for legal regulation, especially in international trade. Further mover, the Metaverse, offering an interactive environment with vast potential, can be utilised in education and training for students and employees. Businesses have been quick, willing, and effective in adopting and implementing new technologies such as virtual reality, blockchain, artificial intelligence, and augmented reality. These technologies are seen as the future of business, offering number opportunities, including increased data interoperability, development of new strategies and business models, and enhanced precision in point cloud data for as-built models of existing facilities [53]. The COVID-19 pandemic has led to an increased interest in virtual life across almost all aspects of human life. Unprecedented before, virtual medical consultations have become a standard, and most corporations, for cost reasons, prefer a hybrid mode of work (both stationary and virtual). This trend extends to property viewing through virtual tours using VR or 360-degree virtual videos and applications in higher education [14][49][51].

In the Metaverse, the graphical elements essentially comprise three components: scenes, which are sets of shapes resembling real-world elements like buildings and monuments; and two types of users: so-called independent (non-player characters) and real users (represented as avatars) [31]. The former are entities that cannot be controlled, as they operate under artificial intelligence, while the later are digital representations of real-life users. The greatest scope for customisation lies with the avatar, allowing users to determine aspects such as facial expressions, outfit, and more [4]. Various platforms facilitate exploration of the virtual world, with the largest being Decentraland ($1.31 billion)[1], Sandbox ($1.31 billion), Theta Network ($1.1 billion), Axie Infinity ($1.01 billion), and Enjin Coin ($474.53 million) [16].

Built upon blockchain architecture, a digital unit of data known as the NFT (non-fungible token) has been developed. Each NFT possesses a unique identification code and distinct metadata, acting as a means of facilitating transactions [20]. However, the primary function of NFTs is to establish ownership of digital assets. These tokens can be purchased on specially designed virtual 'marketplaces' or 'bazaars', such as OpenSea, Axie Marketplace, and Rarible. On these platforms, investors not only engage in buying and selling transactions but can also exchange rights to individual tokens [42]. There are generally six main categories of non-fungible tokens, based on their use: art, collectibles, games, metaverse, other, and utility. The most significant features of NFTs are their uniqueness, traceability, authenticity, and adaptability [11]. The popularity of the NFT market saw a substantial increase in 2020/2021; the daily value of concluded transactions was 183,121 US dollars in 2020, which surged to 38 million dollars in 2021 [42].

Another crucial aspect in the realm of virtual reality trading is cryptocurrency, a type of digital currency specific to each metaverse platform. Unlike NFTs, each cryptocurrency operates on its own individual blockchain. Both cryptocurrencies and the metaverse space are underpinned by the same technological foundation, which significantly contributes to their popularity. This is attributed to their being the simplest, most convenient, and cost-effective means of payment in virtual spaces. Many transactions related to virtual real estate are conducted using cryptocurrencies. When the value of a particular cryptocurrency increases, the worth of virtual properties denominated in that currency may also rise

[1] The values in brackets represent the exchange value of the respective platform in US dollars as of 18 September 2022.

[25]. For instance, an appreciation in the price of Bitcoin could lead to a corresponding increase in the value of virtual properties priced in Bitcoins. Some investors utilise cryptocurrencies both as a means of payment and as an investment in virtual real estate [35]. The rising popularity and value of a specific cryptocurrency can lead to an increase in the value of the virtual properties that can be acquired with it. However, the cryptocurrency market is characterised by high volatility and speculation. Wide fluctuations in cryptocurrency prices can significantly impact the value of virtual properties. Conversely, a decline in a cryptocurrency's value may result in a decrease in the value of virtual properties, expressed in that currency [57]. Nevertheless, it is important to note that virtual properties possess intrinsic value independent of cryptocurrencies. Factors such as the popularity of the virtual world, the uniqueness and appeal of the property, user experience quality, and market supply and demand all influence the value of virtual real estate [52]. While the price of cryptocurrency may be a significant factor, it is not the sole determinant of virtual property values [56]. Examples of cryptocurrencies include MANA (Decentraland), SAND (Sandbox), and AXS/SLP (Axie Infinity) [4]. In the metaverse, intermedia art can be represented through a combination of various NFTs, encompassing elements related to human aesthetic, such as avatars, domains, utilities, or even land [26]. The acquisition of virtual property typically occurs on a 'marketplace', where ownership is secured in the form of an NFT stored on the blockchain, with the transaction conducted in a specific cryptocurrency.

III. DECENTRALAND

The virtual real estate market pertains to the trading, sale, and rental of virtual properties within the digital realm [38]. Virtual properties are digital spaces utilised for various activities, including video games, entertainment, virtual meetings, e-commerce, among others [3]. This market is dynamic, evolving alongside technological advancements and represents an emerging areas of interest for users, developers, investors, and businesses seeking to explore the opportunities provided by the digital virtual space [7][62][64].

Decentralized Finance (DeFi) refers to financial services that operate on blockchain technology, removing intermediaries by enabling peer-to-peer transactions through smart contracts. DeFi enables various applications, including lending, borrowing, and trading without traditional banks or financial institutions. Within the metaverse, Decentralized Finance extends these capabilities to virtual worlds, allowing for secure property transactions, lending, and even leveraging assets for additional investments. Decentraland employs DeFi through its use of MANA, facilitating property transactions directly between users. Another example of DeFi in the metaverse is seen in the platform Sandbox, which uses its native token SAND to enable similar decentralized, peer-to-peer interactions for trading virtual assets, further illustrating the diverse implementations of DeFi in virtual spaces.

The virtual real estate market includes several unique aspects:

- Virtual Worlds: Pertains to three-dimensional, interactive digital environments that users and virtual characters can explore and inhabit. Notable examples are Second Life, Decentraland, VRChat, and Sansar.
- Virtual Property: Users have the opportunity to purchase and own virtual assets, such as houses, apartments, plots of land, or offices within these worlds, gaining control over these spaces.
- Trade and Economy: Governed by the principles of supply and demand, owners may sell, rent, or trade their virtual properties for virtual currency or other digital assets. Platforms exist specifically for the buying and selling of virtual properties.
- Investments and Speculation: Mirroring the physical real estate market, the virtual domain offers investment and speculation opportunities. Certain virtual properties may appreciate in value, attracting investors predicting future value increases.
- Creating Virtual Experiences: Virtual spaces are often used to host experiences like concerts, art exhibitions, conferences, or social events. Businesses and organisations may rent virtual spaces for events or promotional activities, a practice increasingly observed in reality.
- Use of Technology: The interaction with and personalisation of virtual properties are enhanced by technologies such as Virtual Reality (VR), Augmented Reality (AR), blockchain, and cryptocurrencies. These technologies facilitate transaction tracking and ensure the security and authenticity of virtual properties.

Decentraland is the largest and possibly the most popular virtual blockchain world which in existence today [13]. It was the first large-scale blockchain-based virtual world [41]. According to Goldberg et al. (2024), Decentraland has a multi-layered architecture that creates a truly decentralised virtual world, where the supply cannot be increased by anyone, and investors do not face any risks [22]. Decentraland was founded in 2017 by Ariel Meilich and Esteban Ordano. The original design and layout of the sites are shown in ATTACHMENT I. Decentraland consists of four colours that represent roads, with different characteristics (ATTACHMENT II). The lines in light grey represent roads, which are not for sale. The green areas represent plazas, which are places where users are directed upon logging into Decentraland; hence, these areas have a high concentration of users. There are nine such places on the map, each with its own name. When the user logs in for the first time, they are directed to Genesis Plaza, located at the heart of the map, at coordinates 0,0. The dark blue areas are 'districts', which are meeting places for users who share common interests. The dark grey areas represent parcels of land ('parcels') and estates, consisting of two or more parcels, which are the primary focus of transactions.

However, after some time, it became apparent that some districts did not meet the criteria set by Decentraland. As a result, 17 of the existing 56 districts were dissolved in January 2019 (ATTACHMENT II). The status of the parcels forming them

was changed to 'land', and they became subject to market transactions. The largest district is currently Aetheria, with 8,008 parcels, and the smallest is DPR Yetepey, with 28 parcels.

Each user of the platform can acquire ownership of a plot of land or, in the case of several plots of land combined, a property with fixed coordinates on the map. All plots are square-shaped with dimensions of 16m × 16m. Each one has its own coordinates, facilitating navigation for users and enabling investors to purchase the desired plot easily. Decentraland comprises 90,601 individual plots, of which 43,689 are for private use, 33,886 plots are included in 'districts', 9,438 plots are designated as roads and 3,588 plots are included in 'plazas' [23]. FIGURE I shows a sample parcel measuring 16 m × 16 m with a couple of ITEMs on it.

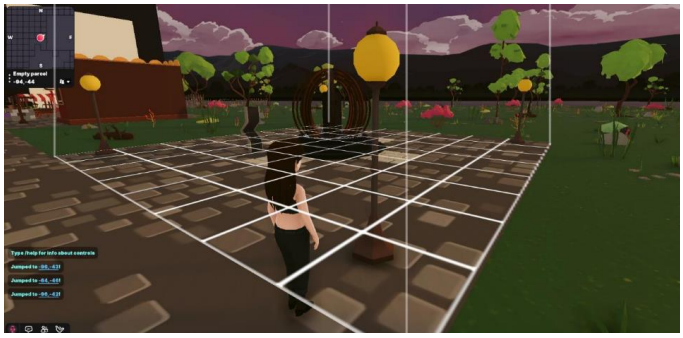

FIGURE I. THE SMALLEST PARCEL SIZES [23].

A plot of land represents the smallest unit available for purchase. An up-to-date map of Decentraland, showing visible development elements, is included in ATTACHMENT III. Eight plazas are observed forming the characteristic shape of an octagon, with the ninth located at its centre. The most intensively developed area is found in the central and south-central parts of Decentraland, which also boast the highest density of roads. In contrast, the least urbanised area is the south-western part, predominantly characterised by undeveloped properties, i.e., those without an ITEM on their site.

The name and price of the property are visible on the home page of the Marketplace. It is possible to sort the properties, with one option being to sort them from the cheapest to the most expensive. It appears that the cheapest property costs 3,390 MANA, while the most expensive property costs 1,000,000,000 MANA (as of 09 Sep 2022; with an exchange rate of 1 MANA = USD 0.80, meaning that the price of the cheapest property is USD 2,712, and the most expensive property is USD 800,000,000). When you click on a property of your choice, details such as the current owner of the property, the distance to amenities like the plaza, district, and road, as well as the transaction history are displayed.

A. Legal Aspects of Metaverse

At the moment, for the most part, there are still no regulations dedicated specifically to the Metaverse environment - their drafting is still under consideration [45][46]. Nevertheless, general regulations related to trademarks, bribery, or selling private data are observed [32]. Transactions recorded on blockchains remain a permanent record, providing some form of protection against theft, yet there is still a growing need for regulation in this kind of market [47]. The Metaverse faces challenges as there are currently no laws that can be directly applied, thus making it a risky area for those who advocate the necessity of regulations and laws for the proper functioning of a global industry. The authors suggest some aspects that must be regulated legally in the future:

1. Data security and privacy: regulations concerning the principles of collection, storage, and processing of data, including users' consent to the use of their data.
2. Intellectual property: copyright and patent protection for creators, along with rules on trade and ownership of virtual objects.
3. Contract and obligation law: enabling users to engage in transactions, enter into contracts, and undertake obligations, with regulations covering the binding force of virtual contracts, dispute resolution, and consumer protection.
4. Security: regulations should include preventative measures against fraud, cyberbullying, etc., and penalties for perpetrators of such activities.
5. Taxation: regulations covering the taxation of virtual transactions, income generated in the Metaverse, and other tax aspects.

In conclusion, it is worth noting that due to the dynamic development of Metaverse technology, regulation will continue to evolve alongside the technology. It is important to monitor this area and introduce new legislation to adapt to the changing realities of the Metaverse and protect social, economic, and legal interests.

B. Metaverse vs NFT

Virtual real estate, akin to NFTs, represents assets within virtual spaces but differs from consumer goods and services in that they are not direct substitutes [59]. This distinction primarily arises because virtual properties exist in virtual worlds and metaviews, signifying that they are digital representations of real estate without physical counterparts in reality, unlike tangible consumer goods and services or those offered as part of a real-world experience [33]. Moreover, virtual real estate is predominantly created and utilised today for entertainment, community-building, or investment purposes [58], serving as spaces where users can meet or interact with others. Conversely, consumer goods and services typically cater to everyday necessities such as food, clothing, health services, and transport [65]. Another notable distinction lies in their investment value; virtual properties, especially in the form of NFTs, often possess investment potential, subject to market speculation and trading [60]. People can buy, sell, and collect NFTs associated with virtual real estate as an investment form. In contrast, consumer goods and services are generally consumed to satisfy immediate needs and are not regarded as investment objects in the same manner [54]. When evaluating the value of NFTs and virtual real estate, it is crucial to recognise that the value of virtual real estate largely hinges on the subjective preferences and expectations of users. For

consumer goods and services, value is often determined by their specific function, utility, and availability [27].

Therefore, although virtual properties may share certain similarities with consumer goods and services, they are not complete substitutes. They represent a distinct domain of digital interaction and experience, unique to virtual worlds and metaviews.

C. Virtual real estate market characteristics

The virtual property market encompasses the trading, buying, and selling of digital properties that exist within virtual worlds rather than physical reality. These virtual properties can assume various forms, such as land, buildings, islands, and decorative objects, available in computer games, virtual worlds, and entertainment platforms. The dynamics of the virtual real estate market often hinge on the popularity and demand for specific games or platforms. Should a particular game gain popularity, the demand for virtual properties within that game increases, potentially leading to higher prices. Similarly, the introduction of an attractive new virtual world or the opportunity to purchase unique properties on a specific platform can attract new players and boost demand. There are also platforms dedicated exclusively to the trading of virtual properties, allowing users to buy, sell, and trade virtual properties with others. Prices for virtual properties are determined by the market based on supply and demand and the value and popularity of the virtual world in question. In some instances, virtual properties may possess external value outside the game, with some players willing to pay significant amounts for rare or unique virtual properties that become collectors' items or hold prestige value within the gaming community. However, it is crucial to recognise that the virtual property market is a unique market often influenced by the decisions and policies of game and platform developers, who can impact the availability, resources, and prices of virtual properties, thereby affecting their market value.

An important factor in the development of virtual properties is the potential for collaboration between leading brands to offer unique experiences. Leading fashion brands including Nike, Adidas, and Reebok have announced partnerships with metaverse start-ups such as RTFKT to offer virtual product listings in the Metaverse [19]. Similar initiatives have been explored by investors through virtual museums and offerings. This collaborative development enables brand enthusiasts to experience new iterations of their favourite concepts and discover innovative entertainment methods. Beyond the real estate landscape, art collections such as Beeple's "Everyday's - The First 5000 Days" have managed to raise over $69 million in partnership with Christie's [39].

While virtual and traditional real estate markets share certain similarities, such as being governed by supply and demand principles, there are notable distinctions. In traditional real estate, property values are influenced by physical location, infrastructure, legal frameworks, and broader economic factors, which often result in gradual and relatively stable appreciation. By contrast, the value of virtual real estate is largely speculative and influenced by platform popularity, user engagement, and cryptocurrency market trends. For example, in Decentraland, the value of properties is closely tied to the value of MANA, a cryptocurrency subject to high volatility. Additionally, while real properties have intrinsic value derived from their physical attributes and utility, virtual properties derive value from digital attributes like proximity to popular virtual locations and the potential for creative digital customization, thus appealing to a different set of investor motivations.

IV. METHODS

The research component of this paper focused on exploring the market for one of the metaverse platforms, Decentraland. This platform, among the most well-known and based on blockchain technology, grants open access to any user, thereby preserving the principles of a free market during transactions. The study focused on Decentraland due to its decentralized structure and the unique role of MANA within its economic framework. Unlike some other platforms where currencies primarily serve speculative purposes, MANA functions both as a transactional utility token and as a measure closely tied to real-world values, providing a stable foundation for evaluating virtual real estate. The data comprised transactions in the virtual properties market and the MANA cryptocurrency exchange rate to the US dollar.

The first task involved selecting sample data (sub-markets), termed fields, evenly distributed across the map. The selection considered the proximity to roads, districts, and plazas, ensuring an even distribution of fields across Decentraland to secure a representative sample of the property market. In total, 12 test fields were chosen, each consisting of 16 individual properties (so-called 'parcels') (ATTACHMENT IV). All test fields are square-shaped, measuring 4×4 parcels, except for field 6, which has a unique shape due to its neighbouring parcels. Consequently, land area was not considered a price factor. Attributes for each parcel were defined, with integer values from 0 to 10, based on their distance from roads, districts, and plazas. The appraisal standards adhered to the International Valuation Standards (IVS) [28] regarding the approach used, the definition of attributes, and their impact on value [24][61]. As a part of the market approach, the statistical analysis method was used, based on Pearson correlation coefficient as a base, and Kendall rank correlation as an auxiliary (checking) coefficient [2][29]. Parcel prices (and their dates) were obtained from the Decentraland marketplace on 15 September 2022.

The second task focuses on the performance of the MANA cryptocurrency against the US dollar. MANA, based on the Ethereum blockchain and linked to Decentraland as a currency, was analysed from its inception (09 November 2017, 1 MANA = 0.015 USD) to the end of the period on 16 September 2022 (MANA/USD 0.726), covering over 4.5 years. The daily exchange MANA/USD rate was illustrated in FIGURE II, with a logarithmic scale on the Y-axis for better interpretation. During the studied period, key moments included: (a) the lowest MANA/USD ratio (21 November 2017), (b) the dissolution of 17 districts (20 January 2019), (c) the official platform launch (20 February 2020), (d) the first MANA peak, and (e) the highest ratio (second peak, 25 November 2021). The official platform launch marked a significant event, with every dollar invested in Decentraland

from that day yielding $12.4 by the end of the analysis period (2.57 years).

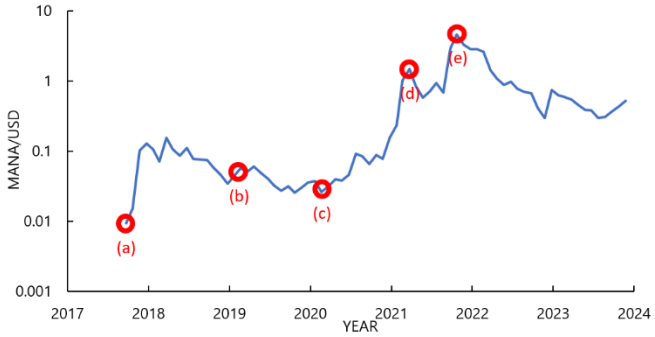

FIGURE II. HISTORICAL MANA/USD EXCHANGE RATE (Yahoo, 2024).

This paper explores the relationship between spatial attributes, property price, and price volatility over time, calculating correlation coefficients. Similar to real estate, a meta-estate is defined by specific attributes such as its location within the platform, its dimensions, ownership rights, and its market value. However, to be more precise, investors may focus on many more attributes. Thus, this analysis takes into account 10 attributes: Field No., Coordinates, ITEM, Road, District, Plaza, Transaction Date, Price [MANA], MANA/USD ratio, Price [USD], and one comment (Current offer price [MANA/USD]).

Overall, in total, the developed dataset comprises 207 records for 103 land parcels (some parcels were sold multiple times) and was organised into 10 – mentioned above – attributes (ATTACHMENT VII). The first property was sold on 14 October 2018, and the last transaction in the analysis period occurred on 18 June 2022.

V. RESULTS

The analysis of Decentraland's property market was based on 12 test fields, evenly distributed across the map, each consisting of 16 (4 × 4) parcels, with their distribution shown in ATTACHMENT IV. All property information and transactional data underpinning the analysis are compiled in ATTACHMENT VII. The results of the property transaction history analysis were visualised in the form of 12 (4 × 4) parcel tables, one for each test field. The table's layout mirrors the field's shape, and each cell represents a single virtual property. For each parcel of land, a cell was assigned the highest transaction price in its (ATTACHMENT V). Additionally, prices are colour-coded for easy differentiation - dark green represents the highest price for a given test plot, while white indicates the lowest price. Highlighting denotes the presence of ITEMs within the respective plot.

The largest number of parcels sold was recorded in test field 7 (located in the central part of Decentraland), with 15 transactions, while the smallest number, 3, was noted for test field 15 (located in the western part). The highest transaction price was achieved by undeveloped properties with coordinates (144, −29) and (144, −30) in test field 3, reaching 34,197 USD. In contrast, the lowest price, 380 USD, was observed for the property with coordinates (55, −121).

To analyse price changes over time, graphs were produced for "triples" of test fields, i.e., graph 1 for test fields 1–3, graph 2 for fields 4–6, graph 3 for fields 7–9, and graph 4 for fields 10–12 (ATTACHMENT IV). These graphs display parcels that were sold at least twice to illustrate how prices have evolved, e.g., parcel (−69, −18) from test field 1 was sold twice - in February 2022 and March 2022 (as per TABLE I). Colours represent the fields in each graph, transactions within a field are distinguished by line types, and markers denote transactions for each parcel.

In the very centre of Decentraland lie fields 6 and 7. Due to their location, the properties in these fields have similar attributes. However, only seven parcels were sold in field 6, compared to as many as 15 in field 7. This discrepancy is also reflected in the average price: for field 6, it was 8,303 USD, while for field 7, it was 12,165 USD. Therefore, the correlation between attributes and price is low. Both fields 2 and 3 are situated in the eastern part of Decentraland and are equidistant from the road. Despite field 2 being located closer to the plaza and district, suggesting greater attractiveness, it recorded fewer transactions (6) than field 3 (12). Moreover, the highest price for field 2 reached 17,157 USD, whereas field 3's highest price was twice as much, at 34,197 USD. Fields 1, 4, and 2 are almost identically positioned relative to the centre of the map, situated between plazas. The largest number of plots was sold in field 1 (9), while the smallest number was sold in field 2 - 6 plots. The average maximum price of the properties was 9,778 USD for field 1 and 8,004 USD for field 2, and 11,484 USD for field 4. Fields 9 and 10, located in the southern part of Decentraland, also share similar attributes. For both fields, 11 parcels were sold. Yet, there is a difference in the average price - 5,371 USD for field 9 and 3,839 USD for field 10. Although this difference is smaller than that between fields 6 and 7, it is still significant.

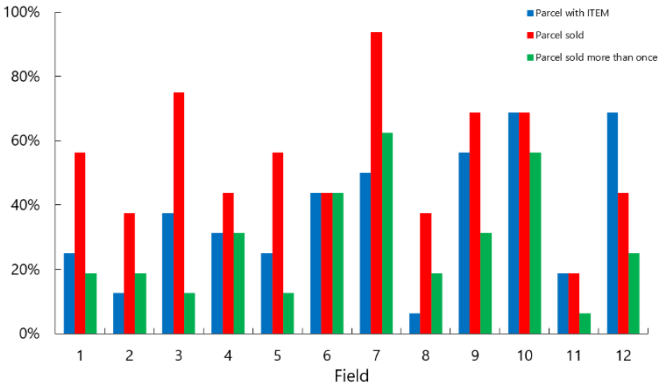

FIGURE III. GRAPH SHOWING THE PERCENTAGE OF PARCELS SOLD, PARCELS SOLD SEVERAL TIMES, AND PARCELS CONTAINING ITEM IN THE ANALYSED FIELDS.

In addition, the impact of attaching ITEMs to properties on their sales was analysed. Furthermore, for each of the test fields, the number of properties sold multiple times was examined (ATTACHMENT VI). The results of these analyses have been compiled in Table I and are also presented in the chart (FIGURE III). The largest number of parcels sold was recorded in test field No. 7, with as many as 15, representing approximately 94% of all properties in that field. This field

also had the highest number of properties that were sold at least twice, with 10 such properties (63%). The high number of transactions in this field can be attributed to its central location on the map. The highest number of properties where ITEM exists was observed in field 12, with 11 (69%). Field 11 was the least successful, with only 3 properties sold, one of which was sold multiple times. In contrast, the smallest number of properties with ITEM was in field 8, with just one such property. The average number of plots sold across all fields is 8.6, the average number of plots with ITEM is 5.9, and the average number of parcels sold multiple times is 4.5.

To examine the impact of each attribute on the property price (in US dollars), a correlation coefficient value was calculated for each attribute (TABLE I), divided into three-time spans: before the platform launch (February 2020), after the launch, and in total. Before the official platform launch, the correlation coefficients indicate that the property price was significantly influenced by the amount of MANA (Price – MANA). The MANA/USD exchange rate was below 10 cents (0.02–0.09), and property costs were relatively low. While the MANA-USD correlation is noteworthy, the market activity may suggest that the primary factor was the belief in the project's success among virtual world enthusiasts rather than market speculation. After the release date, the property market underwent significant changes. The average transaction value increased more than 13-fold (from \$659.76 to \$9074.04). Tests of the mean (Welsh's T-test) and variance (Levene's test) indicate that these represent two distinct property markets, despite the high standard deviation of the means (0.5 and 0.79 respectively). The tests for significant differences (α=0.05) for correlations (transformed by Fisher z-transformation) for Price-Time, Price-MANA, and Price – MANA/USD reject the null hypothesis of equality. In the post-launch market, the Price – MANA and MANA-USD factors indicate that investors are influenced by the value in real currency (US dollar), not the virtual one (Price – MANA factor should be omitted). Thus, the significant factors are time and MANA-US dollar rate. This situation suggests that the real estate market is strongly influenced by speculation on the entire platform (i.e., dependent on external factors) and only slightly by its internal features (e.g., selected property features). It should be noted that the selected attributes were limited, primarily spatially defined, and do not include social factors (e.g., genius loci, etc.).

TABLE I. CORRELATION COEFFICIENTS FOR PRICE AND OTHER ATTRIBUTES BEFORE AND AFTER THE OFFICIAL PLATFORM RELEASE.

Correlation values	**The Decentraland periods**		
	Before launch (<Feb. 2020)	After launch (>Feb. 2020)	Total (Oct. 2018–June 2022)
Price - Time	−0.22	0.59	0.72
Price - ITEM	−0.08	−0.22	−0.14
Price - Road	0.00	0.18	0.20
Price - District	−0.14	0.01	0.02
Price - Plaza	−0.03	−0.03	−0.07
Price - MANA	0.73	−0.45	−0.53
Price - MANA/USD	0.63	0.88	0.93

Other aspects that might affect a parcel's price are not measurable and cannot be accurately estimated. The value of real estate in Decentraland stems from a combination of traditional market mechanisms and the unique characteristics of the virtual world. Factors such as location, infrastructure development, income generation potential, cryptocurrency fluctuations, and community engagement are key determinants. In the long term, the value of LAND will depend on the success of Decentraland as a platform and the growing interest in the Metaverse and blockchain, which may lead to increased demand for virtual real estate. Plots of land can be rented out or used for activities such as virtual shops, events, or brand promotions. The more traffic an area receives, the greater its potential for revenue generation. Additionally, community involvement and visits to the Decentraland world enhance the attractiveness of properties. Another contributing factor can be the plot's history—if it has previously been used by well-known brands, its value can increase. Furthermore, announcements of new features, partnerships, or developments on Decentraland can also raise the value of properties.

VI. DISCUSSION

Metaverse platforms offer users the opportunity to meet others online. Additionally, owning property can yield profits. Decentraland, in particular, due to its decentralised structure, grants complete freedom to acquire and then dispose of property. Property owners have access to a wide range of solutions, including the placement of digital skyscrapers, palaces, and art galleries, among others. However, it is important to note that this market is relatively new and carries considerable risk.

The analysis covered 207 sales across 103 land parcels: 82 before (2017–2020) and 125 after the platform's launch (2020–2022). The virtual currency (MANA) to US dollar exchange rate served as a reference.

The virtual property market is highly volatile, marked by its dependence on the virtual currency (MANA) to the US dollar rate. From the released day (02.2020) to the end of the analysed period (09.2002), the currency increased from 0.05 to 0.73 MANA per US dollar. This indicates that every dollar invested from the launch day yielded \$12.4 in 2.57 years. Consequently, the values of analysed virtual properties increased more than 13-fold on average. Before the official

release, property values were relatively low, correlating only with Price-to-MANA and Price-to-MANA/US dollar rate. This situation might suggest that the market was primarily driven by metaverse enthusiasts, inclined to invest in the "game" rather than in property market. After the launch day, statistically significant changes in correlation were observed: the price to time factor became significant (from −0.22 to 0.59), the price to MANA/US correlation rose to a high level (from 0.63 to 0.88), and the price to MANA shifted from strong correlated (0.73) to an average level of negative correlation (−0.45).

Other property attributes were selected by following the International Valuation Standards in terms of the approach used, the definition of attributes, and their impact on value [24][61]. The considered factors were mostly limited to spatial ones, based on the distance from roads, districts, and plazas. The analysis did not include social factors (e.g., genius loci, etc.). The chosen method (Pearson correlation) yielded negative results: no correlation was found between these factors and the price of the property. This outcome is quite unusual, as investors would typically prefer plots closer to the aforementioned locations due to the greater likelihood of visitation, which aligns with the primary purpose of investing in Decentraland - to attract other users. The location's proximity to the city centre also seems to have a slight impact on the price. This can be justified by the fact that within the platform, any user can move their avatar to any location using the teleportation tool, which requires only a few clicks. The presence of ITEMs on a property, described as 0 (ITEMs free) and 1 (existing ITEMs), has a very slight negative correlation (−0.22) with the price.

In general, the proposed attributes that could potentially generate price had little impact on property prices. This indicates that valuation using the comparative approach is not viable. Similarly, valuation through the income approach is unfeasible, as the virtual property itself is not profitable; it can merely serve as a venue for product advertisement. The cost approach is inherently not applicable as virtual objects do not deteriorate. Therefore, following the International Valuation Standards, it may be concluded that virtual properties on the Decentraland platform cannot be evaluated as real estate. Moreover, the impact of MANA/US dollar rate on properties suggests that they should not be valuated separately (as real estate), but rather in conjunction with the MANA currency. This means that evaluations should employ methods from the financial markets.

Given the high volatility of the Decentraland environment, it is crucial to consider that factors which currently have no impact on a property's value may become significant in the near future, both positively and negatively. The study focused primarily on real estate trading. However, virtual reality may offer numerous opportunities, such as advertising products or organising cultural events, which could influence the property market and its valuation. The advantages of investing in Decentraland real estate include the relatively easy acquisition of property, the possibility of making a quick profit with minimal effort, and accessibility to users worldwide. On the downside, the high volatility of cryptocurrencies and the need for creativity and technical skills to develop the property, despite the simplicity of the purchase process, are notable disadvantages.

To contextualise these findings, a comparison between virtual and physical real estate markets highlights the unique investment risks and valuation challenges faced in the metaverse. In addition to the specific valuation factors analysed, it is critical to consider the broader speculative dynamics, and oversupply risks inherent to virtual real estate markets. The rapid development and expansion of platforms like Decentraland, Sandbox, and other metaverse spaces expand the supply of virtual properties, potentially leading to market saturation. Such oversupply could dilute the value of individual assets and intensify speculative trading, as users and investors may perceive limited long-term value in a market with minimal physical constraints. The speculative nature of these assets, largely tied to fluctuating cryptocurrency values, may exacerbate volatility, complicating valuation stability in the metaverse. These dynamics underscore the need for continuous monitoring of supply-demand equilibrium in virtual markets, which may help mitigate the risk of bubbles and abrupt valuation declines. This comparison not only underscores the divergent dynamics of virtual and physical markets but also emphasises the importance of developing tailored investment strategies for the metaverse.

The comparison of virtual and physical real estate markets highlights significant differences in investment risks and valuation perspectives. In traditional real estate markets, investment risks are generally tied to physical factors such as property location, infrastructure, market conditions, and legal frameworks, which provide a degree of stability and predictability. Investors can rely on established valuation methods, including comparative market analysis, income-based approaches, and cost analysis, all of which are grounded in tangible, regulated assets. In contrast, virtual real estate markets, like Decentraland, present unique investment risks. These include extreme market volatility driven by cryptocurrency fluctuations, platform-specific factors, and speculative trading behaviours. The value of virtual properties is often linked to non-tangible attributes, such as proximity to popular virtual locations, community engagement, and the presence of notable digital assets or events. For example, properties in high-traffic virtual districts or those used for brand collaborations may command premium prices, despite lacking physical constraints. From a valuation perspective, traditional real estate benefits from well-defined methodologies and regulatory oversight. However, virtual real estate relies heavily on speculative and subjective factors. Decentraland's virtual properties, for instance, cannot be evaluated using conventional real estate valuation methods such as the cost approach, as virtual assets do not deteriorate over time. Instead, valuation in the metaverse requires integrating financial market methodologies, accounting for cryptocurrency exchange rates, platform growth, and user demand. Furthermore, investment risks in virtual markets are amplified by the lack of established regulations and the potential for market saturation. The speculative nature of virtual assets, coupled with the rapid expansion of metaverse platforms, creates uncertainty for long-term value stability.

Conversely, physical real estate investments are supported by enduring demand and intrinsic utility, offering a more predictable return on investment. These differences underscore the need for prospective virtual property investors to adopt a cautious approach, considering both the opportunities and the inherent risks. While the virtual market offers the potential for significant short-term gains, particularly in high-demand platforms like Decentraland, it also requires a higher tolerance for risk and a deep understanding of digital market dynamics. Future research could further explore strategies to mitigate these risks and enhance valuation methods, bridging the gap between traditional and virtual real estate markets.

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AUTHORS` CONTRIBUTIONS

All authors have participated in drafting the manuscript. All authors read and approved the final version of the manuscript. Author contribution percentages are as follows: DN 35%, CAGS 10%, LB 10%, MA 10%, KM 35%.

CONFLICT OF INTEREST

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

DATA AVAILABILITY

The data supporting the findings of this study are available upon request from the authors.

ETHICAL STATEMENT

In this article, the principles of scientific research and publication ethics were followed. This study did not involve human or animal subjects and did not require additional ethics committee approval.

REFERENCES

[1] @carrotcake. (2018). Decentraland: An Epic Virtual World Powered by Cryptocurrency.

[2] Abdi, H. (2007). The Kendall Rank Correlation. In Encyclopedia of Measurement and Statistics. Thousand Oaks (CA): Sage. https://personal.utdallas.edu/~herve/Abdi-KendallCorrelation2007-pretty.pdf

[3] Adegoke, A. S., Oladokun, T. T., Ayodele, T. O., Agbato, S. E. & Jinadu, A. A. (2022). DEMATEL method of analysing the factors influencing the decision to adopt virtual reality technology by real estate firms in Lagos property market. Smart and Sustainable Built Environment, 11(4), 891–917. https://doi.org/10.1108/SASBE-09-2020-0135

[4] Akkus, H. T., Gursoy, S., Dogan, M. & Demir, A. B. (2022). Metaverse and metaverse cryptocurrencies (meta coins): bubbles or future. Pressacademia, 9, 22–29. https://doi.org/10.17261/pressacademia.2022.1542

[5] Al-Gnbri, M. K. A. (2022). Accounting and Auditing in the Metaverse World from a Virtual Reality Perspective: A Future Research. Journal of Metaverse, 2(1), 29–41.

[6] Allouzi, A. S. & Alomari, K. M. (2023). Adequate legal rules in settling metaverse disputes: Hybrid legal framework for metaverse dispute resolution (HLFMDR). International Journal of Data and Network Science, 7(4), 1627–1642. https://doi.org/10.5267/j.ijdns.2023.8.001

[7] Anderson, K. C., Freybote, J. & Manis, K. T. (2022). The Impact of Virtual Marketing Strategies on the Price-TOM Relation. Journal of Real Estate Finance and Economics. https://doi.org/10.1007/S11146-022-09908-X

[8] Ante, L., Wazinski, F. P. & Saggu, A. (2023). Digital real estate in the metaverse: An empirical analysis of retail investor motivations. Finance Research Letters, 58(31), 1–14. https://doi.org/10.1016/j.frl.2023.104299

[9] Ball, M. (2020). The metaverse: What It Is, Where to Find it, and Who Will Build It.

[10] Ball, M. (2022). The Metaverse and how it will revolutionize everything. Liveright.

[11] Bao, H. & Roubaud, D. (2022). Non-Fungible Token: A Systematic Review and Research Agenda. Journal of Risk and Financial Management, 15(5). https://doi.org/10.3390/jrfm15050215

[12] Bartels, N. & Hahne, K. (2023). Teaching Building Information Modeling in the Metaverse—An Approach Based on Quantitative and Qualitative Evaluation of the Students Perspective. Buildings, 13(9). https://doi.org/10.3390/buildings13092198

[13] blockee.co. (2024). What Are The Most Popular Virtual Worlds?

[14] Chen, C. & Yao, M. Z. (2022). Strategic use of immersive media and narrative message in virtual marketing: Understanding the roles of telepresence and transportation. Psychology and Marketing, 39(3), 524–542. https://doi.org/10.1002/mar.21630

[15] Clark, P. A. (2021). What is the Metaverse? Here's Why It Matters. Time.

[16] Coinmarketcap. (2022). Top Metaverse Tokens by Market Capitalization.

[17] Jach, W., Hubar, Y., Trojański, P., Maciuk, K. (2023) Trends in primary apartments market during COVID-19 pandemic. Budownictwo i Architektura. 22(4), 27–37. https://doi.org/10.35784/bud-arch.3728

[18] Duan, H., Li, J., Fan, S., Lin, Z., Wu, X. & Cai, W. (2021). Metaverse for Social Good: A University Campus Prototype. MM 2021 - Proceedings of the 29th ACM International Conference on Multimedia, 153–161. https://doi.org/10.1145/3474085.3479238

[19] Egede, I. (2022). Reebok joins the Metaverse bandwagon after Nike and Adidas. Crypto.News.

[20] Febriandika, N. R., Fadli, F. & Mi'raj, D. A. (2022). How are NFT (Non-Fungible Token) transactions reviewed according to Islamic law? Borobudur Law Review, 3(1), 1–12.

[21] Gartner. (2022). Predicts 2022: 4 technology bets for building the digital future. Gartner Report.

[22] Goldberg, M., Kugler, P. & Schär, F. (2024). Land valuation in the metaverse: location matters. In Journal of Economic Geography (Vol. 24, Issue August). https://doi.org/10.1093/jeg/lbae027

[23] Güven, İ. & Ercan, T. (2022). Determining Factors of Virtual Land Value: The Case of Decentraland. ITESDES: International Technology Sciences and Design Symposium, July, 518–537.

[24] Hasan, G. M. J., Jabir, A. Al & Anam, M. M. (2022). Monitoring bank-line movements of the rivers flowing across the Sundarbans using remote sensing and GIS techniques. Regional Studies in Marine Science, 56. https://doi.org/10.1016/j.rsma.2022.102679

[25] Hirsch, P. B. (2022). Adventures in the metaverse. Journal of Business Strategy, 43(5), 332–336. https://doi.org/10.1108/JBS-06-2022-0101

[26] Hong, R. & He, H. (2021). Interference and Consultation in Virtual Public Space: The Practice of Intermedia Art in Metaverse. Proceedings - 2021 17th International Conference on Mobility, Sensing and Networking, MSN 2021, 792–797. https://doi.org/10.1109/MSN53354.2021.00124

[27] Hwang, Y. (2023). When makers meet the metaverse: Effects of creating NFT metaverse exhibition in maker education. Computers and Education, 194. https://doi.org/10.1016/J.COMPEDU.2022.104693

[28] IVSC. (2021). International Valuation Standards. https://viewpoint.pwc.com/dt/gx/en/ivsc/international_valuat/assets/IVS-effective-31-Jan-2022.pdf

[29] Kendall, M. G. . & Gibbons, J. D. (1990). Rank correlation methods. E. Arnold ; Oxford University Press. https://search.worldcat.org/title/21195423

[30] Kęsy, M. (2014). Rzeczywistość wirtualna w procesie kształcenia technicznego. Edukacja-Technika-Informatyka, 42–47.

[31] Kosciesza, A. J. (2022). The Moral Service of Trans NPCs: Examining the Roles of Transgender Non-Player Characters in Role-Playing Video Games. Games and Culture, 155541202210881. https://doi.org/10.1177/15554120221088118

[32] Kostenko, O., Furashev, V., Zhuravlov, D. & Dniprov, O. (2022). Genesis of Legal Regulation Web and the Model of the Electronic Jurisdiction of the Metaverse. Bratislava Law Review, 6(2), 21–36. https://doi.org/10.46282/blr.2022.6.2.316

[33] Lee, J. & Kwon, K. H. (2022). Novel pathway regarding good cosmetics brands by NFT in the metaverse world. Journal of Cosmetic Dermatology, 21(12), 6584–6593. https://doi.org/10.1111/JOCD.15277

[34] Lee, U. K. & Kim, H. (2022). UTAUT in Metaverse: An "Ifland" Case. Journal of Theoretical and Applied Electronic Commerce Research, 17(2), 613–635. https://doi.org/10.3390/jtaer17020032

[35] Mackenzie, S. (2022). Criminology Towards the Metaverse: Cryptocurrency Scams, Grey Economy and the Technosocial. The British Journal of Criminology, 62(6), 1537–1552. https://doi.org/10.1093/bjc/azab118

[36] Marin, O., Cioara, T., Toderean, L., Mitrea, D. & Anghel, I. (2023). Review of Blockchain Tokens Creation and Valuation. Future Internet, 15(12), 382. https://doi.org/10.3390/fi15120382

[37] Marketplace. (2022). Marketplace (Land).

[38] Miljkovic, I., Shlyakhetko, O. & Fedushko, S. (2023). Real Estate App Development Based on AI/VR Technologies. Electronics (Switzerland), 12(3). https://doi.org/10.3390/ELECTRONICS12030707

[39] Mittal, A. (2021). Metaverse riding on NFT boom, says owner of $69 million digital artwork. The Economic Times.

[40] NFZ Plazas. (2022). Decentraland Map.

[41] Ordano, E., Meilich, A., Jardi, Y. & Araoz, M. (2017). Decentraland: A Blockchain-based Virtual World.

[42] Pinto-Gutiérrez, C., Gaitán, S., Jaramillo, D. & Velasquez, S. (2022). The NFT Hype: What Draws Attention to Non-Fungible Tokens? Mathematics, 10(3). https://doi.org/10.3390/math10030335

[43] Poux, P. (2022). A Unified Framework for the Governance of the Commons with Blockchain-Based Tools: An Application to Customary Land Commons in Ghana. SSRN Electronic Journal, 1–40. https://doi.org/10.2139/ssrn.4077127

[44] Ritterbusch, G. D. & Teichmann, M. R. (2023). Defining the Metaverse: A Systematic Literature Review. IEEE Access, 11, 12368–12377. https://doi.org/10.1109/ACCESS.2023.3241809

[45] Rosenberg, L. (2022). Regulation of the Metaverse: A Roadmap The risks and regulatory solutions for largescale consumer platforms. ACM International Conference Proceeding Series, July, 21–26. https://doi.org/10.1145/3546607.3546611

[46] Rosenberg, L. B. (2022). Regulating the Metaverse, a Blueprint for the Future. Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 13445 LNCS, 263–272. https://doi.org/10.1007/978-3-031-15546-8_23

[47] Rosenberg, L. B. (2023). The Growing Need for Metaverse Regulation. Lecture Notes in Networks and Systems, 544 LNNS(September), 540–547. https://doi.org/10.1007/978-3-031-16075-2_39

[48] Sarmah, G. (2020). The Emergence of Block chain Technology and its Economic Significance. Journal of Critical Reviews, 07(13), 4485–4491.

[49] Shwedeh, F. (2024). Harnessing digital issue in adopting metaverse technology in higher education institutions: Evidence from the United Arab Emirates. International Journal of Data and Network Science, 8(1), 489–504. https://doi.org/10.5267/j.ijdns.2023.9.007

[50] Siwak, W. (2016). Matrix i pół-Matrix czyli rzeczywistość wirtualna i rzeczywistość rozszerzona jako wyzwania dla tożsamości, kultury, sztuki i edukacji. Rocznik Naukowy Kujawsko-Pomorskiej Szkoły Wyższej w Bydgoszczy, 11, 355–388.

[51] Solaiman, B. (2023). Telehealth in the Metaverse: Legal & Ethical Challenges for Cross-Border Care in Virtual Worlds. Journal of Law, Medicine and Ethics, 51(2), 287–300. https://doi.org/10.1017/jme.2023.64

[52] Syuhada, K., Tjahjono, V. & Hakim, A. (2023). Dependent Metaverse Risk Forecasts with Heteroskedastic Models and Ensemble Learning. Risks, 11(2), 32. https://doi.org/10.3390/risks11020032

[53] Tesmer, V., Steigenberger, P., van Dam, T. & Mayer-Gürr, T. (2011). Vertical deformations from homogeneously processed GRACE and global GPS long-term series. Journal of Geodesy, 85(5), 291–310. https://doi.org/10.1007/s00190-010-0437-8

[54] Thenjono, K., Ratana, F. & Hendratno, S. P. (2022). The Business Prospect in Metaverse and NFT Era (User, Accountant, and Gaming Community Perspectives). 2022 4th International Conference on Cybernetics and Intelligent System, ICORIS 2022. https://doi.org/10.1109/ICORIS56080.2022.10031392

[55] van der Merwe, D. F. (2022). The metaverse as virtual heterotopia. 3rd World Conference on Research in Social Sciences. https://doi.org/10.33422/3rd.socialsciencesconf.2021.10.61

[56] Vidal-Tomás, D. (2022). The new crypto niche: NFTs, play-to-earn, and metaverse tokens. Finance Research Letters, 47, 102742. https://doi.org/10.1016/j.frl.2022.102742

[57] Vidal-Tomás, D. (2023). The illusion of the metaverse and meta-economy. International Review of Financial Analysis, 86, 102560. https://doi.org/10.1016/j.irfa.2023.102560

[58] Wang, C., Yu, C. & Li, Y. (2022). Toward Understanding Attention Economy in Metaverse: A Case Study of NFT Value. IEEE Transactions on Computational Social Systems. https://doi.org/10.1109/TCSS.2022.3221669

[59] Wang, C., Yu, C. & Zhang, Y. (2022). Attention Economy in Metaverse: An NFT Value Perspective. 2022 IEEE 24th International Workshop on Multimedia Signal Processing, MMSP 2022. https://doi.org/10.1109/MMSP55362.2022.9949153

[60] Wang, M. & Lau, N. (2023). NFT Digital Twins: A Digitalization Strategy to Preserve and Sustain Miao Silver Craftsmanship in the Metaverse Era. Heritage, 6(2), 1921–1941. https://doi.org/10.3390/HERITAGE6020103

[61] Wang, Y., Tang, P., Liu, K., Cai, J., Ren, R., Lin, J. J., Cai, H., Zhang, J., El-Gohary, N., Berges, M. & Golparvar Fard, M. (2023). Characterizing Data Sharing in Civil Infrastructure

Engineering: Current Practice, Future Vision, Barriers, and Promotion Strategies. Journal of Computing in Civil Engineering, 37(2). https://doi.org/10.1061/jccee5.cpeng-5077

[62] Xiong, C., Cheung, K. S., Levy, D. S. & Allen, M. (2022). The effect of virtual reality on the marketing of residential property. Housing Studies. https://doi.org/10.1080/02673037.2022.2074971

[63] Yahoo. (2024). Decentraland USD (MANA-USD).

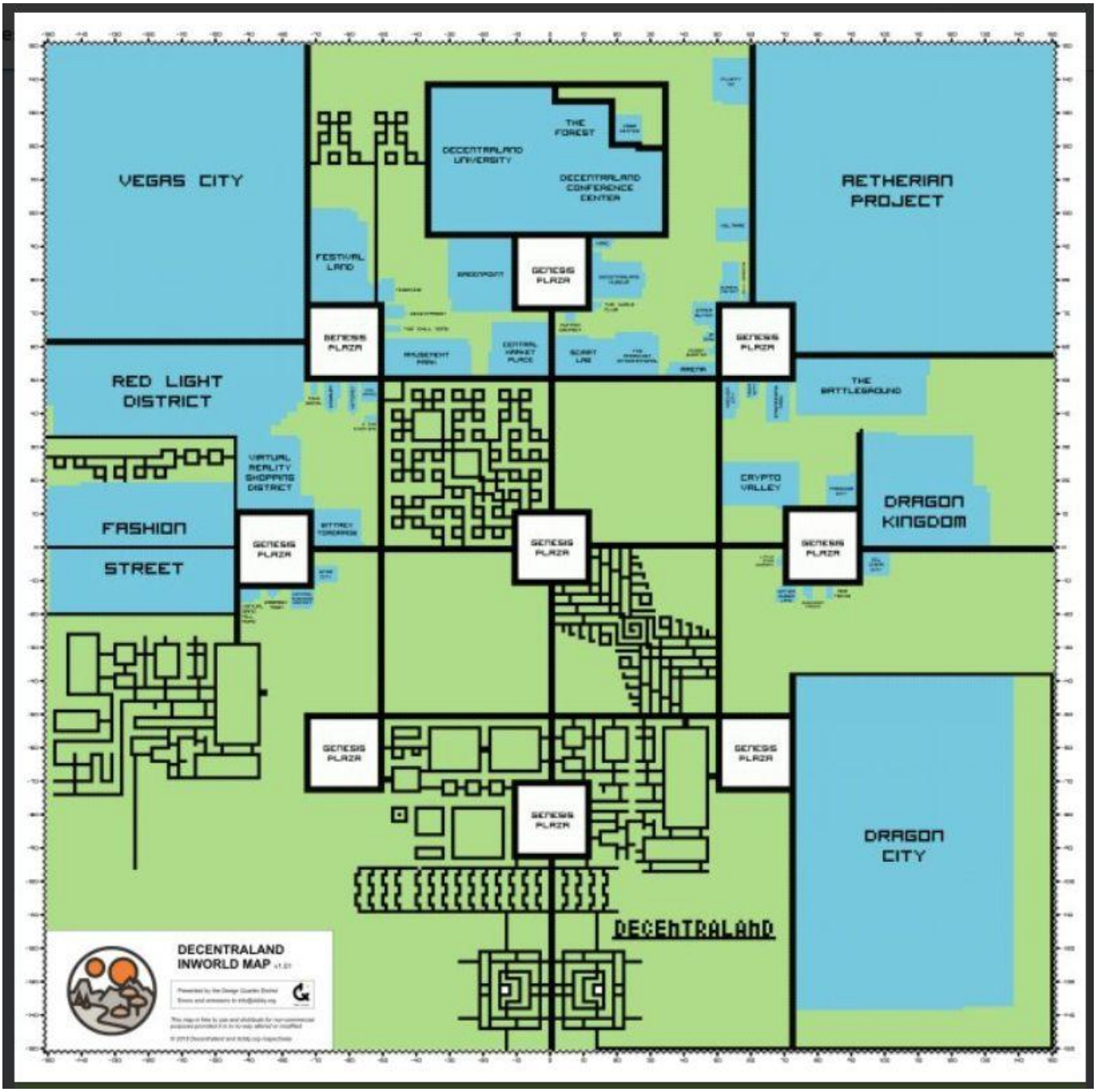
[64] Yasnitsky, L. N., Yasnitsky, V. L. & Alekseev, A. (2022). Simulation of Residential Real Estate Markets in the Largest Russian Cities. Economy of Regions, 18(2), 609–622. https://doi.org/10.17059/EKON.REG.2022-2-22

[65] Zelenyanszki, D., Hóu, Z., Biswas, K. & Muthukkumarasamy, V. (2023). A privacy awareness framework for NFT avatars in the metaverse. 2023 International Conference on Computing, Networking and Communications, ICNC 2023, 431–435. https://doi.org/10.1109/ICNC57223.2023.10074107

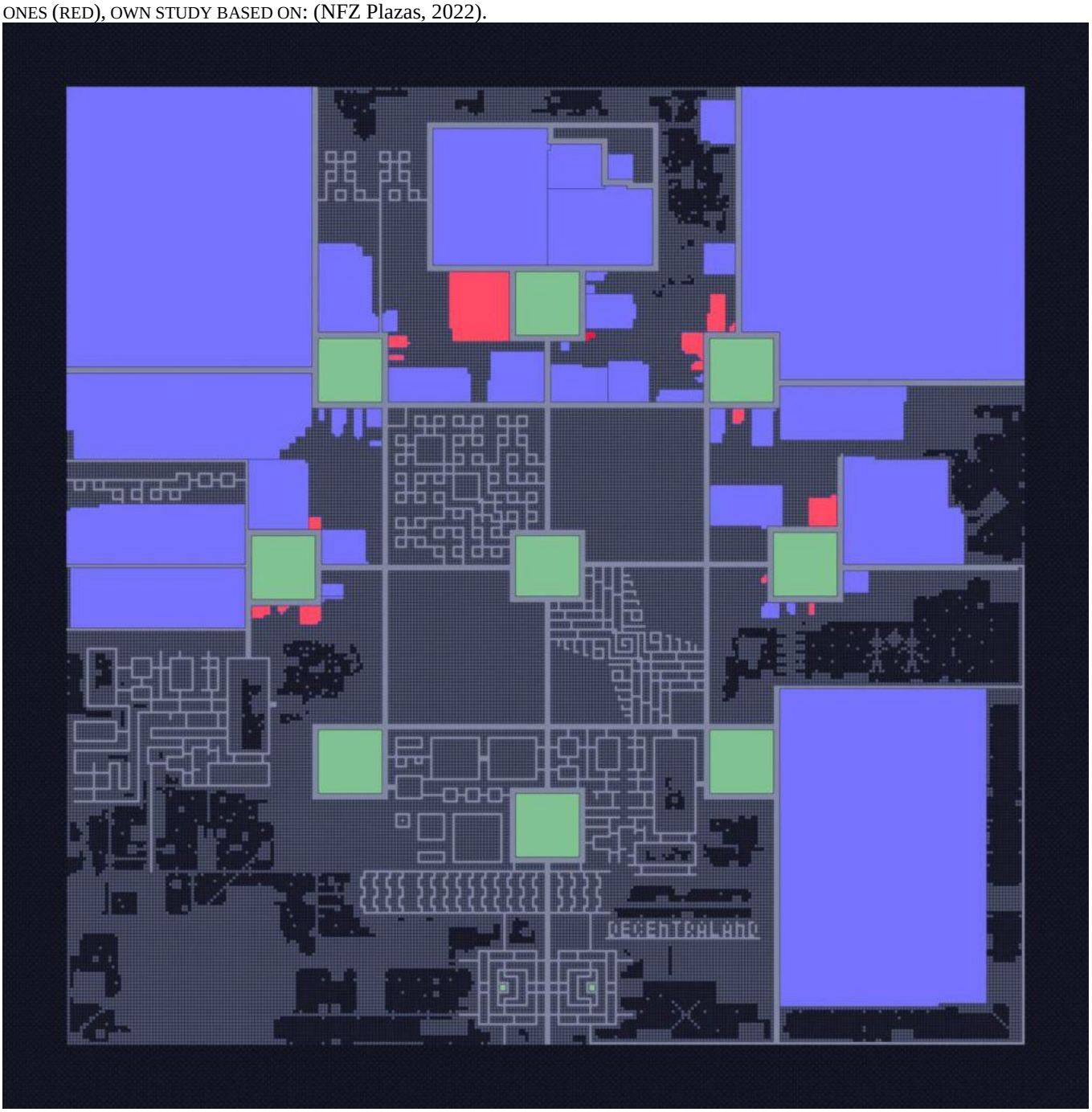
[66] Zenou, T. (2022). A novel predicted the metaverse (and hyperinflation) 30 years ago. The Washington Post.

[67] Zhao, Y., Jiang, J., Chen, Y., Liu, R., Yang, Y., Xue, X. & Chen, S. (2022). Metaverse: Perspectives from graphics, interactions and visualization. Visual Informatics, 6(1), 56–67. https://doi.org/10.1016/j.visinf.2022.03.002

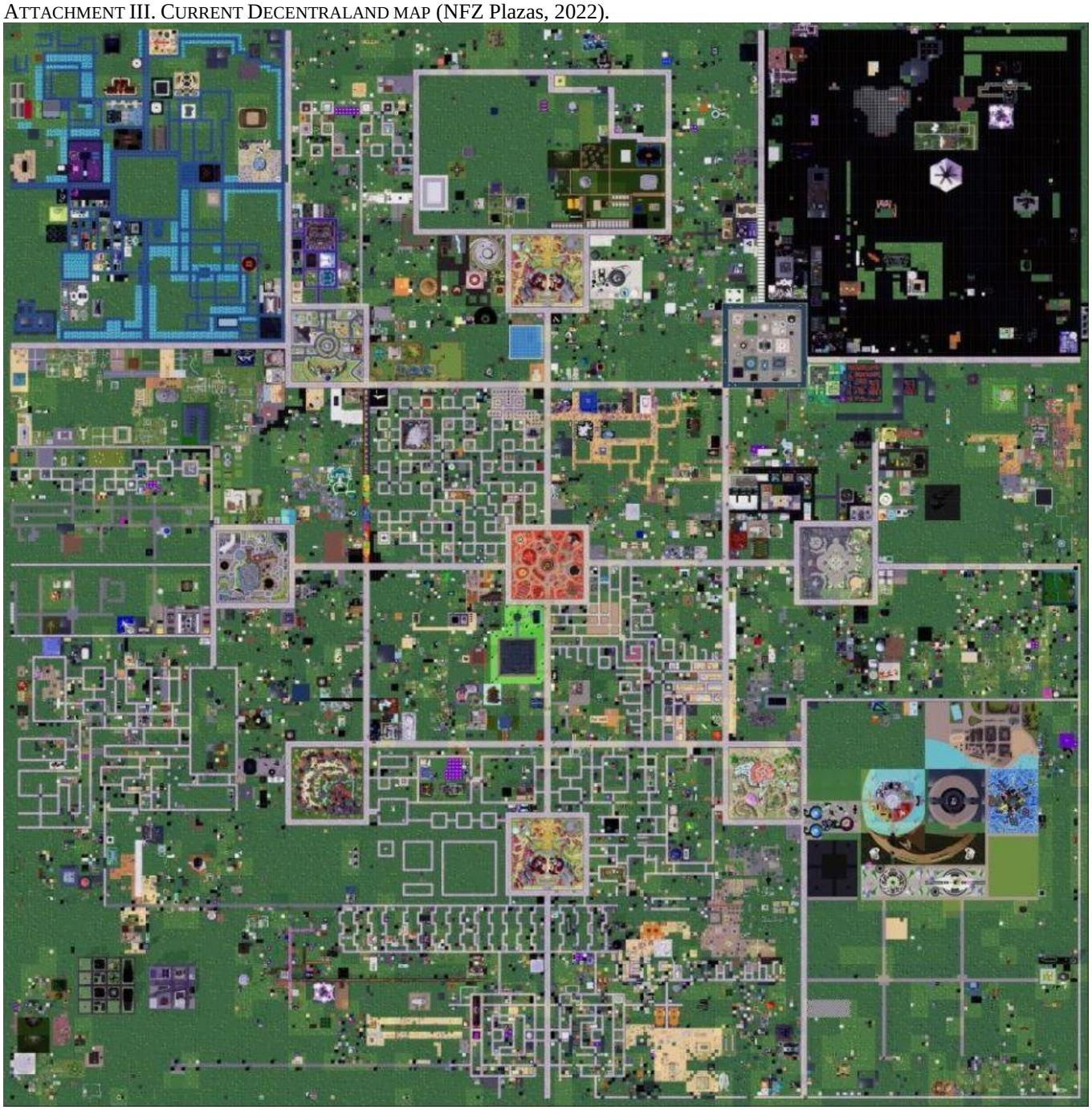
ATTACHMENT I. VERY FIRST MAP - DISTRICT VIEW OF DECENTRALAND MAP BY DESIGN QUARTER (@carrotcake, 2018).



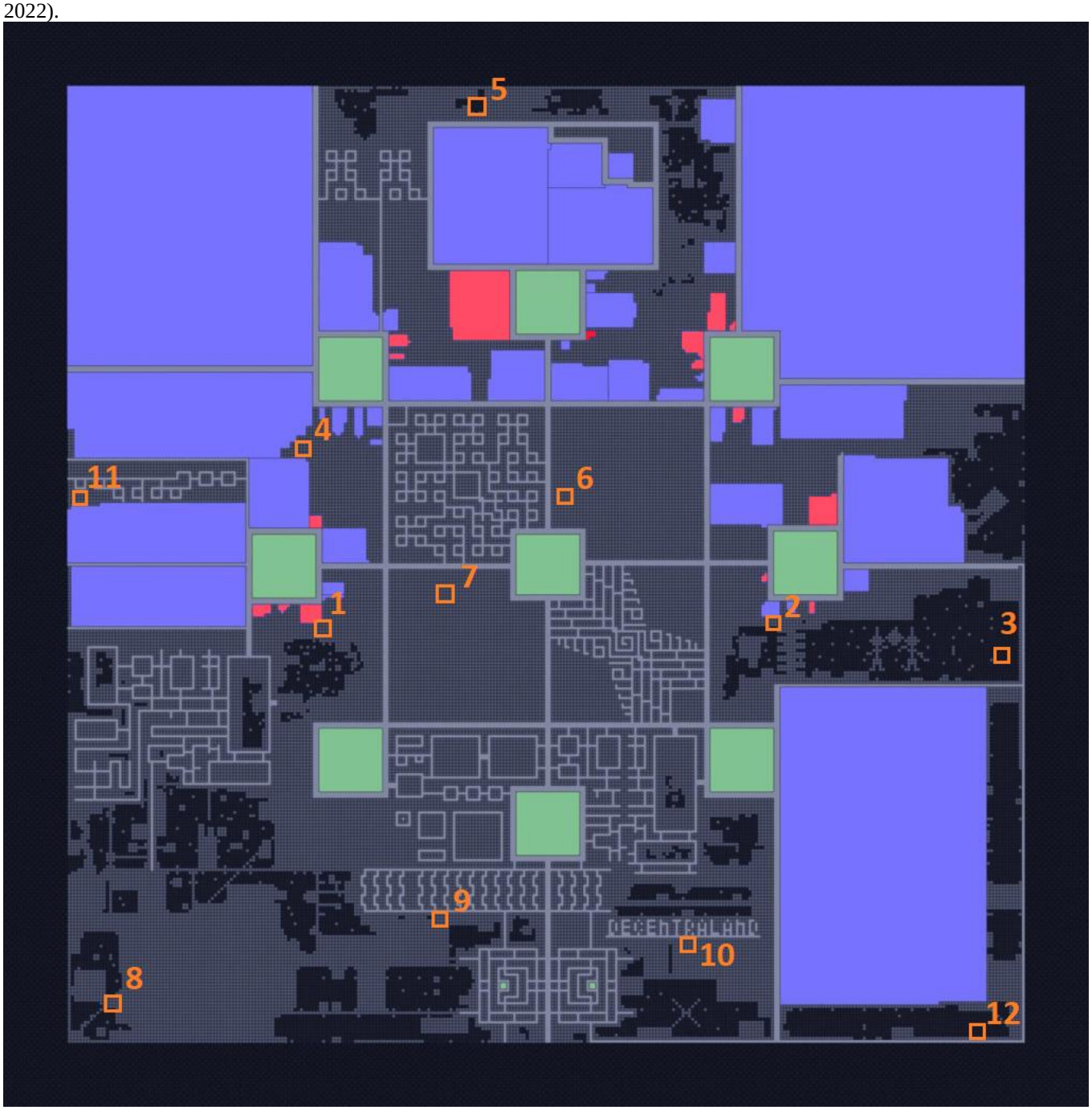
ATTACHMENT II. JANUARY 2019: DECENTRALAND MAP HIGHLIGHTING: CURRENT DISTRICTS (DARK BLUE) AND DISSOLVED ONES (RED), OWN STUDY BASED ON: (NFZ Plazas, 2022).



ATTACHMENT III. CURRENT DECENTRALAND MAP (NFZ Plazas, 2022).



ATTACHMENT IV. LOCATION OF 12 TEST FIELDS (ORANGE) ANALYSED IN THE STUDY, OWN STUDY BASED ON: (NFZ Plazas, 2022).



ATTACHMENT V. PRICES IN AN ANALYSED FIELD

Field 1

	4867		15196
15263			14317
		11490	11088
5325	779	9680	

Field 2

17157	800	11113	
		1050	
		17105	
800			

Field 3

	4539	14606	14606
	15496	14490	18200
	15603	13398	34197
	15603	16591	34197

Field 4

		1920	
6120		18500	
		14552	17576
	16675		5047

Field 5

10725	9781		10163
			10163
460	12998	1100	
	12845	599	

Field 6

10299	1063		1245
		22519	
	8519		1500
		12978	

Field 7

4 897	4 859	14 395	3 100
4 253	17 312	24 325	5 398
15 433	26 004	13 074	5 392
23 181	15 886	4 968	

Field 8

743			
		625	
	475	524	
499	15675		

Field 9

1056	1000	13836	1320
3416	16682	17133	2842
719	540		540

Field 10

2480		1160	15776
543	570	7187	595
380	600		
500	12436		

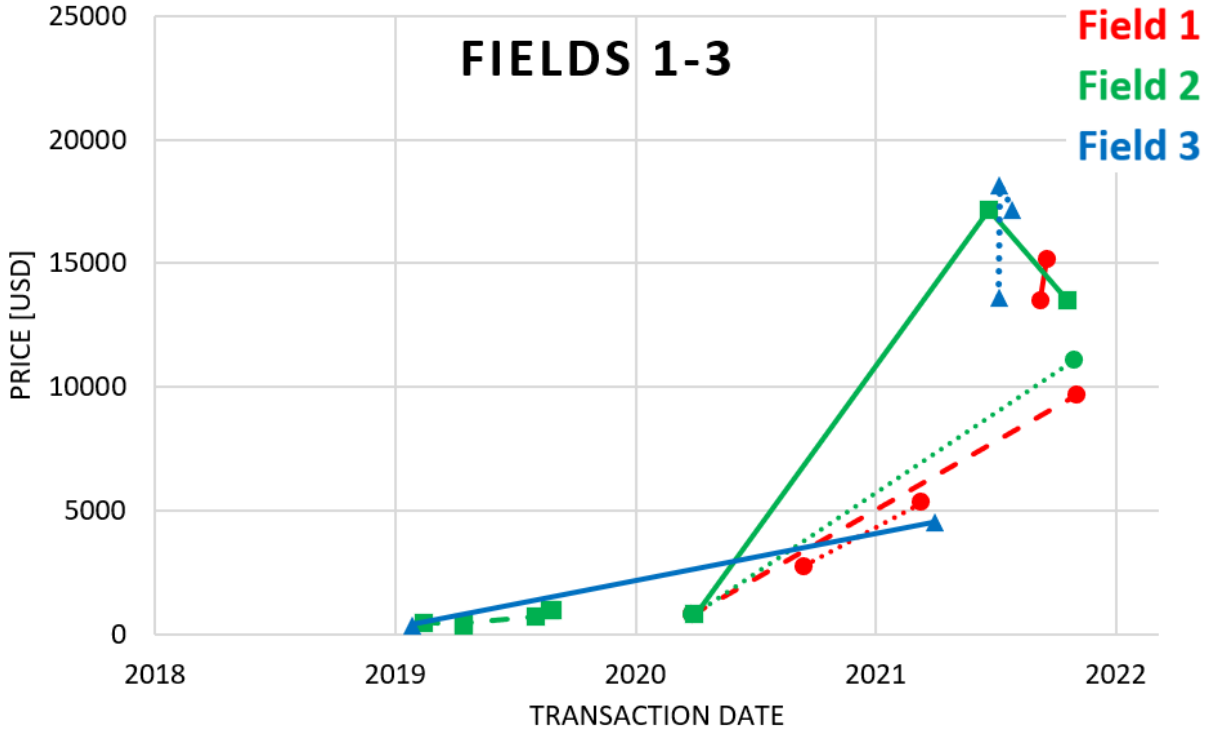
Field 11

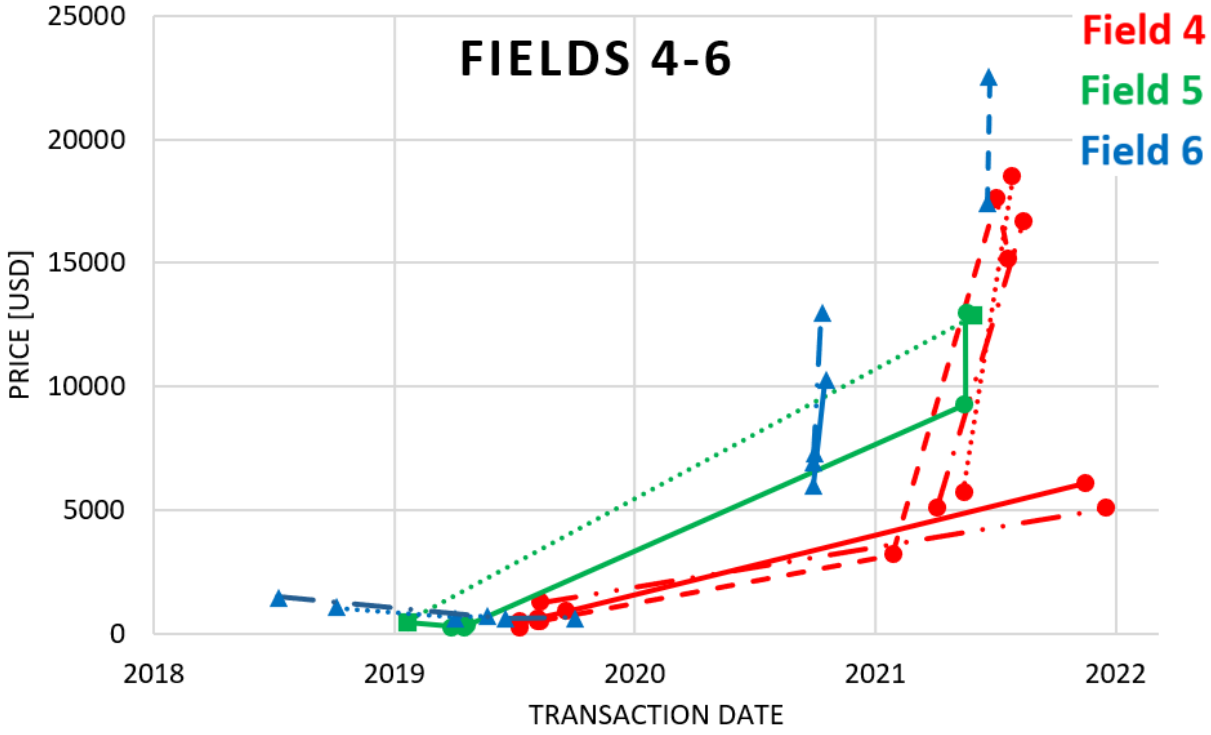
			7014
			14214
			4228

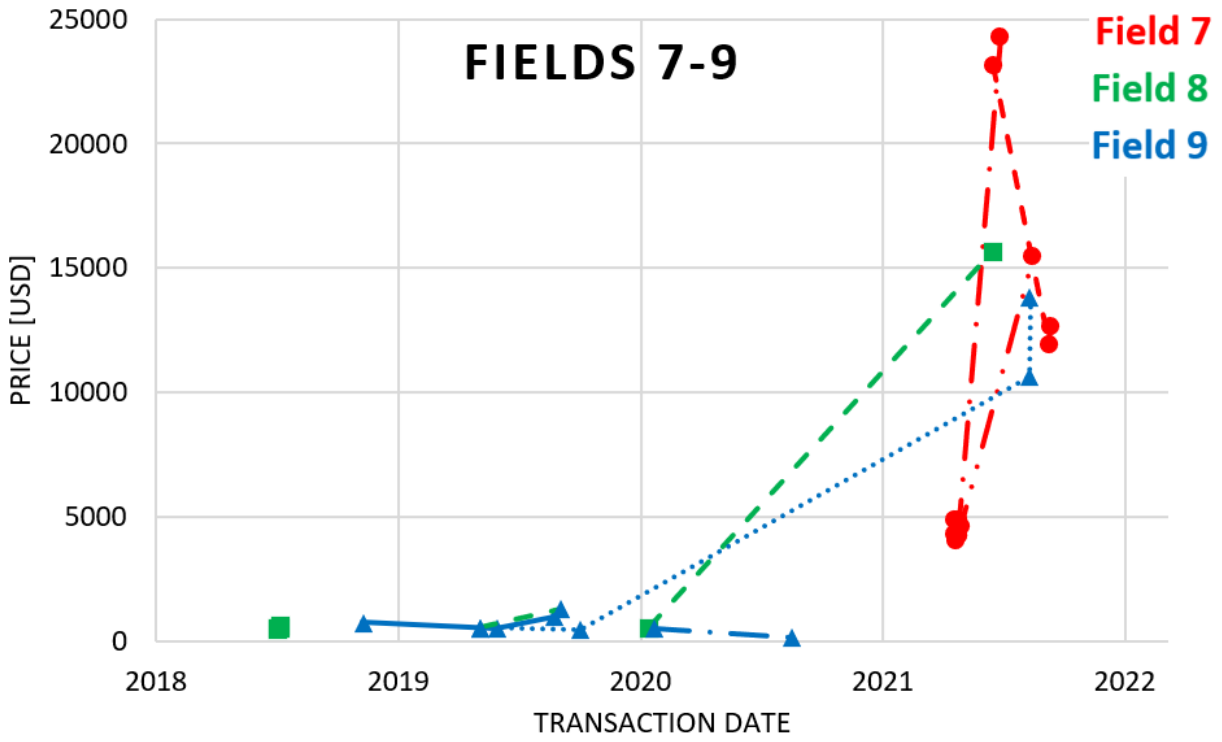
Field 12

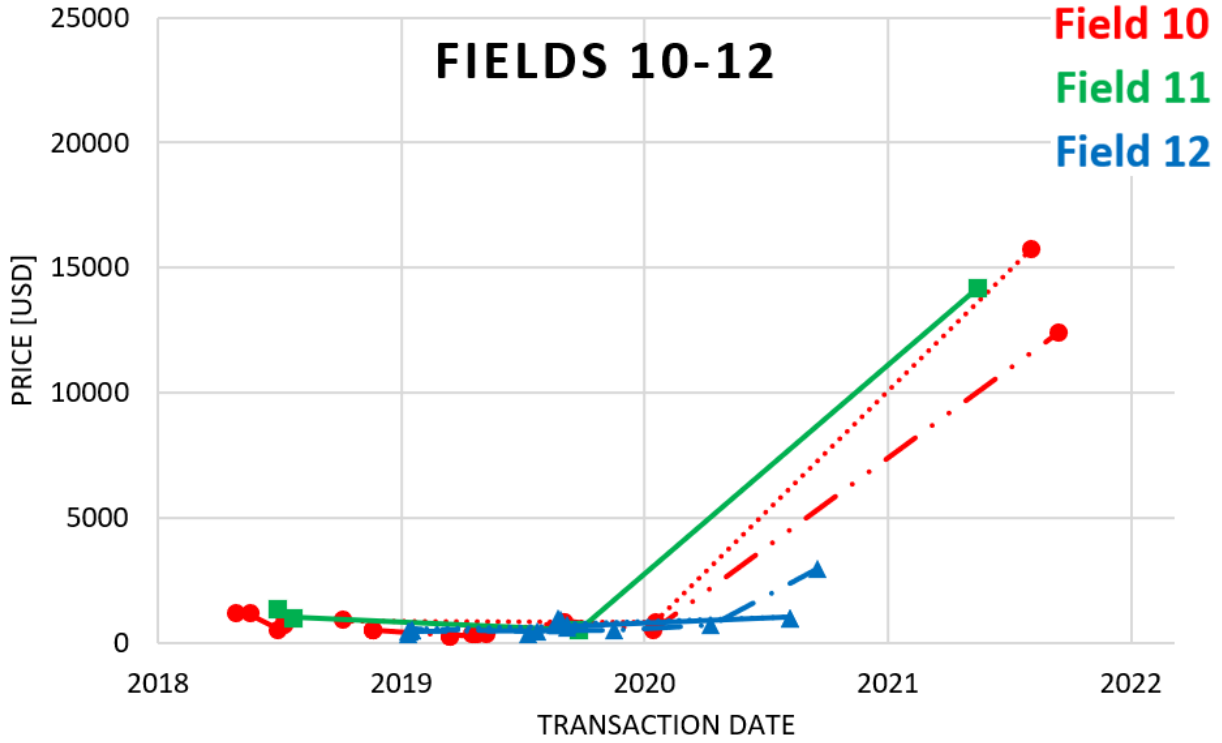
569		1014	1014
11422			12190
12190			2970

ATTACHMENT VI. TRANSACTIONS PRICE CHANGES OF THE SAME PARCELS SINCE DECENTRALAND ESTABLISHMENT, GRAPHS BELOW SHOWS PARCELS SOLD MORE THAN ONCE AND ITS PRICES CHANGES IN TIME









ATTACHMENT VII. TRANSACTIONS IN ANALYSED FIELDS (MARKETPLACE, 2022) (ACCESS DATE: 15 SEP 2022)

Field no	Coordinates	Item	Road	District	Plaza	Transaction date	Price [MANA]	MANA/ USD	Price [USD]	Current offer price[2] [MANA/USD]
1	(-72, -18)		5	6	7					
	(-71, -18)		5	6	7	21.11.2021	5,233	0.93	4,867	
	(-70, -18)		5	6	7					
	(-69, -18)	+	5	6	7	22.02.2022	5,250	2.58	13,545	
						4.03.2022	5,800	2.62	15,196	
	(-72, -19)		6	7	8	12.02.2022	5,245	2.91	15,263	
	(-71, -19)		6	7	8					
	(-70, -19)		6	7	8					
	(-69, -19)		6	7	8	23.02.2022	5,150	2.78	14,317	
	(-72, -20)		7	8	9					
	(-71, -20)		7	8	9					
	(-70, -20)	+	7	8	9	23.01.2022	5,420	2.12	11,490	
	(-69, -20)	+	7	8	9	27.03.2022	4,200	2.64	11,088	8,000 MANA/5,840 USD
	(-72, -21)	+	8	9	10+	1.03.2021	11,000	0.25	2,750	
						26.08.2021	5,788	0.92	5,325	
	(-71, -21)		8	9	10+	10.09.2020	9,735	0.08	779	
	(-70, -21)		8	9	10+	10.09.2020	10,000	0.08	800	9,999 MANA/7,299 USD
						20.04.2022	4,420	2.19	9,680	
	(-69, -21)		8	9	10+					
2	(70, -17)	+	5	0	7	16.09.2020	10,000	0.08	800	
						6.12.2021	5,199	3.30	17,157	
						5.04.2022	5,100	2.65	13,515	
	(71, -17)	+	5	0	7	20.09.2020	10,000	0.08	800	
	(72, -17)		5	0	7	12.09.2020	10,000	0.08	800	13,950 MANA/10,184 USD
						16.04.2022	5,169	2.15	11,113	
	(73, -17)		5	0	7					
	(70, -18)		6	1	8					
	(71, -18)		6	1	8					
	(72, -18)		6	1	8	31.07.2019	12,300	0.04	492	
						1.10.2019	12,500	0.03	375	
						1.10.2019	16,000	0.03	480	
						18.01.2020	18,000	0.04	720	
						9.02.2020	15,000	0.07	1,050	
						11.02.2020	17,400	0.06	1,044	
	(73, -18)		6	1	8					
	(70, -19)		7	2	9					
	(71, -19)		7	2	9					
	(72, -19)		7	2	9	6.02.2022	5,500	3.11	17,105	
	(73, -19)		7	2	9					
	(70, -20)		8	3	10+	19.06.2020	19,999	0.04	800	
	(71, -20)		8	3	10+					
	(72, -20)		8	3	10+					
	(73, -20)		8	3	10+					
3	(141, -27)	+	8	10+	10+					
	(142, -27)	+	7	10+	10+	15.07.2019	9,725	0.04	389	
						14.09.2021	5,469	0.83	4,539	
	(143, -27)		6	10+	10+	28.11.2021	3,088	4.73	14,606	
	(144, -27)		5	10+	10+	28.11.2021	3,088	4.73	14,606	
	(141, -28)	+	8	10+	10+					
	(142, -28)		7	10+	10+	3.12.2021	3,587	4.32	15,496	
	(143, -28)		6	10+	10+	18.12.2021	4,200	3.45	14,490	20,000 MANA/14,600 USD
	(144, -28)		5	10+	10+	21.12.2021	4,200	3.25	13,650	

[2] Exchange rate 1 MANA = 0.73 USD at 15 Sep 2022

						23.12.2021	5,600	3.25	18,200	
						11.01.2022	6,200	2.77	17,174	
	(141, -29)	+	8	9	10+					
	(142, -29)	+	7	9	10+	2.12.2021	3,587	4.35	15,603	
	(143, -29)		6	9	10+	14.12.2021	4,200	3.19	13,398	
	(144, -29)		5	9	10+	10.02.2021	9,999	3.42	34,197	
	(141, -30)	+	7	8	10+					
	(142, -30)		7	8	10+	2.12.2021	3,587	4.35	15,603	
	(143, -30)		6	8	10+	9.12.2021	4,366	3.8	16,591	
	(144, -30)		5	8	10+	10.02.2021	9,999	3.42	34,197	
4	(-78, 38)	+	10+	0	10+					
	(-77, 38)		10+	1	10+					
	(-76, 38)		10+	2	10+	3.11.2018	23,999	0.08	1,920	
	(-75, 38)	+	10+	2	10+					
	(-78, 37)		10+	1	10+	25.12.2019	9,000	0.03	270	
						27.12.2019	13,440	0.04	538	
						21.01.2020	14,500	0.04	580	
						21.01.2020	16,000	0.04	640	
						4.03.2020	22,000	0.04	880	
						4.05.2022	4,000	1.53	6,120	
	(-77, 37)		10+	1	10+					
	(-76, 37)		10+	2	10+	29.10.2021	5,000	1.14	5,700	
						12.01.2022	6,250	2.96	18,500	
	(-75, 37)		10+	3	10+					
	(-78, 36)		10+	2	10+					
	(-77, 36)		10+	2	10+					
	(-76, 36)	+	10+	2	10+	2.11.2021	4,450	3.27	14,552	20,000 MANA/14,600 USD
	(-75, 36)		10+	2	10+	27.01.2020	18,000	0.03	540	
						14.07.2021	5,225	0.61	3,187	
						19.12.2021	5,200	3.38	17,576	
						6.01.2022	5,287	2.87	15,174	
	(-78, 35)		10+	1	10+					
	(-77, 35)		10+	1	10+	19.09.2021	6,249	0.82	5,124	
						28.01.2022	7,444	2.24	16,675	
	(-76, 35)	+	10+	1	10+					
	(-75, 35)	+	10+	1	10+	27.01.2020	21,000	0.06	1,260	
						4.06.2022	5,150	0.98	5,047	
5	(-24, 146)	+	6	8	10+	3.11.2021	3,750	2.86	10,725	
	(-23, 146)	+	6	8	10+	3.11.2021	3,420	2.86	9,781	
	(-22, 146)		6	8	10+					
	(-21, 146)		6	8	10+	8.11.2021	3,750	2.71	10,163	
	(-24, 145)		5	7	10+					
	(-23, 145)		5	7	10+					
	(-22, 145)		5	7	10+					
	(-21, 145)		5	7	10+	8.11.2021	3,750	2.71	10,163	
	(-24, 144)	+	4	6	10+	1.07.2019	9,195	0.05	460	
	(-23, 144)		4	6	10+	8.07.2019	9,490	0.05	475	
						13.09.2019	9,900	0.03	297	
						3.10.2019	8,000	0.03	240	
						8.10.2019	12,700	0.03	381	
						1.11.2021	3,000	3.09	9,270	
						2.11.2021	3,975	3.27	12,998	
	(-22, 144)		4	6	10+	18.01.2021	9,999	0.11	1,100	
	(-21, 144)		4	6	10+					
	(-24, 143)		3	5	10+					
	(-23, 143)	+	3	5	10+	9.07.2019	9,850	0.05	493	
						13.11.2021	3,500	3.67	12,845	

	(-22, 143)		3	5	10+	24.12.2018	9,985	0.06	599	
	(-21, 143)		3	5	10+					
6	(4, 23)	+	2	10+	10+	15.03.2021	6,000	1.00	6,000	Closed area; 15,000 MANA/10,950 USD
						3.04.2021	9,999	1.03	10,299	
	(5, 23)	+	3	10+	10+	23.03.2019	21,250	0.05	1,063	
						19.09.2019	22,500	0.03	675	
						7.11.2019	24,001	0.03	720	
	(6, 23)		4	10+	10+					
	(7, 23)	+	5	10+	10+	3.02.2020	24,900	0.04	996	100,000 MANA/73,000 USD
						24.02.2020	24,900	0.05	1,245	
	(8, 23)		6	10+	10+					
	(4, 22)		2	10+	10+					
	(5, 22)	+	3	10+	10+					
	(6, 22)		4	10+	10+	4.12.2021	5,250	3.31	17,378	
						9.12.2021	5,926	3.80	22,519	
	(7, 22)		5	10+	10+					
	(4, 21)	+	2	10+	10+					
	(5, 21)	+	3	10+	10+	22.03.2021	8,000	0.97	7,760	
						12.05.2021	5,999	1.42	8,519	
	(6, 21)		4	10+	10+					
	(7, 21)		5	10+	10+	24.12.2018	25,000	0.06	1,500	
						4.12.2019	30,000	0.02	600	
						19.03.2020	34,000	0.02	680	
	(4, 20)		2	10+	10+					
	(5, 20)		3	10+	10+					
	(6, 20)	+	4	10+	10+	14.03.2021	6,688	1.04	6,956	
						17.03.2021	8,900	0.82	7,298	
						27.03.2021	14,420	0.90	12,978	
7	(-34, -7)		5	10+	10+	4.10.2021	5,450	0.79	4,306	
						4.10.2021	6,199	0.79	4,897	
	(-33, -7)		5	10+	10+	9.10.2021	5,200	0.81	4,212	
						9.10.2021	5,999	0.81	4,859	
	(-32, -7)	+	5	10+	10+	9.10.2021	5,200	0.81	4,212	
						26.04.2022	7,420	1.94	14,395	
	(-31, -7)	+	5	10+	10+	21.02.2021	9,999	0.31	3,100	
	(-34, -8)		6	10+	10+	9.10.2021	5,250	0.81	4,253	
	(-33, -8)		6	10+	10+	9.10.2021	5,200	0.81	4,212	
						5.11.2021	6,789	2.55	17,312	
	(-32, -8)		6	10+	10+	9.10.2021	5,200	0.81	4,212	
						12.12.2021	6,891	3.53	24,325	
	(-31, -8)	+	6	10+	10+	4.09.2021	5,190	1.04	5,398	
						16.05.2022	4,299	1.18	5,073	
	(-34, -9)		7	10+	10+	6.10.2021	5,450	0.74	4,033	
						13.10.2021	6,199	0.74	4,587	
						30.01.2022	6,100	2.53	15,433	
	(-33, -9)	+	7	10+	10+	25.11.2021	4,888	5.32	26,004	
	(-32, -9)		7	10+	10+	9.03.2022	3,678	2.52	9,269	
						9.03.2022	5,188	2.52	13,074	
	(-31, -9)	+	7	10+	10+	20.11.2018	26,000	0.06	1,560	
						4.09.2021	5,185	1.04	5,392	
	(-34, -10)	+	8	10+	10+	1.12.2021	5,140	4.51	23,181	
						23.02.2022	4,300	2.78	11,954	
						25.02.2022	4,899	2.59	12,688	
	(-33, -10)	+	8	10+	10+	17.11.2021	4,888	3.25	15,886	
	(-32, -10)	+	8	10+	10+	24.10.2021	6,288	0.79	4,968	
	(-31, -10)		8	10+	10+		,			
8	(-138, -136)		10+	10+	10+	11.03.2019	14,850	0.05	743	
	(-137, -136)	+	10+	10+	10+					

	(-136, -136)		10+	10+	10+					
	(-135, -136)		10+	10+	10+					
	(-138, -137)		10+	10+	10+					
	(-137, -137)		10+	10+	10+					7,800 MANA/5,694 USD
	(-136, -137)		10+	10+	10+	21.12.2018	10,800	0.05	540	
						21.12.2018	12,490	0.05	625	
	(-135, -137)		10+	10+	10+					
	(-138, -138)		10+	10+	10+					
	(-137, -138)		10+	10+	10+	20.12.2018	9,500	0.05	475	
	(-136, -138)		10+	10+	10+	20.12.2018	9,500	0.05	475	
						20.12.2018	10,489	0.05	524	
	(-135, -138)		10+	10+	10+					
	(-138, -139)		10+	10+	10+	16.12.2018	9,988	0.05	499	
	(-137, -139)		10+	10+	10+	1.07.2020	14,567	0.04	583	
						30.11.2021	3,335	4.70	15,675	
	(-136, -139)		10+	10+	10+					
	(-135, -139)		10+	10+	10+					
9	(-36. -110)	+	0	10+	10+	10.03.2019	21,111	0.05	1,056	
	(-35, -110)	+	0	10+	10+	26.04.2019	15,339	0.05	767	
						13.11.2019	17,200	0.03	516	
						8.02.2020	20,000	0.05	1,000	
	(-34, -110)	+	0	10+	10+	20.10.2019	18,900	0.03	567	
						19.03.2020	22,000	0.02	440	
						24.01.2022	5,750	1.85	10,638	
						26.01.2022	6,095	2.27	13,836	
	(-33, -110)		0	10+	10+	20.10.2019	18,900	0.03	567	
						18.02.2020	22,000	0.06	1,320	
	(-36, -111)		1	10+	10+	7.03.2021	8,990	0.38	3,416	
	(-35, -111)		1	10+	10+	1.12.2021	3,699	4.51	16,682	
	(-34, -111)	+	1	10+	10+	01,12.2021	3,799	4.51	17,133	
	(-33, -111)	+	1	10+	10+	4.07.2021	4,900	0.58	2,842	
	(-36, -112)	+	2	10+	10+	10.11.2018	7,990	0.09	719	
	(-35, -112)	+	2	10+	10+	18.03.2020	13,499	0.02	270	
						4.07.2020	13,500	0.04	540	
	(-34, -112)	+	2	10+	10+					
	(-33, -112)	+	2	10+	10+	6.07.2020	13,500	0.04	540	
						2.02.2021	8,500	0.02	170	
	(-36, -113)		3	10+	10+					
	(-35, -113)		3	10+	10+					
	(-34, -113)		3	10+	10+					
	(-33, -113)		3	10+	10+					
10	(55, -119)	+	1	10+	10+	9.07.2021	4,000	0.62	2,480	
	(56, -119)		1	10+	10+					
	(57, -119)		1	10+	10+	14.10.2018	16,485	0.07	1,154	
						3.11.2018	14,500	0.08	1,160	
						16.12.2018	10,985	0.05	549	
						24.12.2018	12,000	0.06	720	
						24.12.2018	12,900	0.06	774	
	(58, -119)	+	1	10+	10+	21.03.2019	17,500	0.05	875	
						3.07.2020	21,000	0.04	840	
						18.01.2022	5,555	2.84	15,776	
	(55, -120)	+	2	10+	10+	6.05.2019	10,000	0.05	500	
						8.05.2019	10,850	0.05	543	
	(56, -120)	+	2	10+	10+	15.05.2019	8,250	0.05	413	30,000 MANA/21,900 USD
						16.05.2019	9,500	0.06	570	
	(57, -120)		2	10+	10+	18.03.2021	5,200	1.07	5,564	
						1.04.2021	6,911	1.04	7,187	
	(58, -120)	+	2	10+	10+	22.08.2019	10,000	0.03	300	

						29.08.2019	9,100	0.03	273	
						6.10.2020	8,500	0.07	595	
	(55, -121)	+	3	10+	10+	13.08.2019	9,500	0.04	380	
						5.09.2019	9,890	0.03	297	
	(56, -121)	+	3	10+	10+	21.06.2019	9,999	0.06	600	15,000 MANA/10,950 USD
	(57, -121)	+	3	10+	10+					
	(58, -121)		3	10+	10+					
	(55, -122)	+	4	10+	10+	8.05.2019	9,999	0.05	500	
						29.08.2019	9,699	0.03	291	
						8.10.2019	10,900	0.03	327	
						24.10.2019	11,000	0.03	330	
	(56, -122)	+	4	10+	10+	29.08.2019	9,699	0.03	291	
						4.10.2019	10,900	0.03	327	
						12.10.2019	12,950	0.03	389	
						16.02.2020	13,900	0.06	834	
						21.02.2020	14,250	0.06	855	
						30.06.2020	12,480	0.04	499	
						28.02.2022	4,820	2.58	12,436	
	(57, -122)		4	10+	10+					
	(58, -122)	+	4	10+	10+					
11	(-148, 22)		1	3	10+					
	(-147, 22)	+	1	3	10+					
	(-146, 22)		1	3	10+					
	(-145, 22)	+	1	3	10+	16.03.2021	6,945	1.01	7,014	
	(-148, 21)		2	2	10+					
	(-147, 21)		2	2	10+					
	(-146, 21)		2	2	10+					
	(-145, 21)		2	2	10+					
	(-148, 20)		3	1	10+					
	(-147, 20)		3	1	10+					
	(-146, 20)		3	1	10+					
	(-145, 20)	+	3	1	10+	14.12.2018	27,500	0.05	1,375	
						8.01.2019	20,999	0.05	1,050	
						12.03.2020	17,990	0.03	540	
						1.11.2021	4,600	3.09	14,214	
	(-148, 19)		4	0	10+					
	(-147, 19)		4	0	10+					
	(-146, 19)		4	0	10+					
	(-145, 19)		4	0	10+	18.06.2022	5,351.89	0.79	4,228	
12	(134, -145)	+	4	7	10+	5.07.2019	9,488	0.06	569	
	(135, -145)	+	4	7	10+					
	(136, -145)	+	4	7	10+	25.12.2019	11,888	0.03	357	
						22.02.2020	13,500	0.05	675	
						20.01.2021	7,800	0.13	1,014	
	(137, -145)	+	4	7	10+	27.06.2019	8,000	0.05	400	
						5.07.2019	8,999	0.06	540	
						7.02.2020	13,777	0.05	689	
						9.02.2020	14,111	0.07	988	
						23.02.2020	15,000	0.05	750	
						20.01.2021	7,800	0.13	1,014	
	(134, -146)	+	3	8	10+	3.04.2022	4,246	2.69	11,422	
	(135, -146)	+	3	8	10+					
	(136, -146)	+	3	8	10+					
	(137, -146)		3	8	10+	27.06.2019	8,300	0.05	415	
						5.07.2019	9,700	0.06	582	
						7.01.2020	11,500	0.04	460	
						10.02.2020	11,500	0.06	690	

						10.02.2020	12,000	0.06	720	
						10.02.2020	12,890	0.06	773	
						11.02.2020	14,999	0.06	900	
	(134, -147)		2	9	10+	9.11.2021	4,600	2.65	12,190	
	(135, -147)		2	9	10+					
	(136, -147)	+	2	9	10+					
	(137, -147)	+	2	9	10+	1.07.2019	8,999	0.05	450	
						3.05.2020	13,333	0.04	533	
						27.09.2020	8,887	0.08	711	
						3.03.2021	9,900	0.30	2,970	
	(134, -148)	+	1	10+	10+					
	(135, -148)		1	10+	10+					
	(136, -148)		1	10+	10+					
	(137, -148)	+	1	10+	10+					