

## Characterizing Historical Patterns of Forest Ownership and Parcelization in McKean County, Pennsylvania

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### Introduction

The modern United States cadastral system, or system of recording property rights, is rooted in 16<sup>th</sup> and 17<sup>th</sup> century post-colonial land claims. To this day, land is considered by the U.S. government to be a resource that can be bought and sold by individuals, organizations, and government entities. The Land Ordinance of 1785 is a good example of how the U. S. government formed a system to control how land was surveyed, how it could be acquired, and whom could acquire it. Dividing land into uniform and congruent shapes was a convenient way for the government to track and maintain records of ownership and for wealthy European men and their associated organizations to claim wide swaths of the U.S. as their own. This also resulted in a race between parties with conflicting interests to acquire land that they deemed valuable for their purposes. Companies interested in extracting resources from the land, conservation organizations that want to preserve those resources, individuals and companies that want to acquire land as an investment, and government agencies that want to preserve land for recreation all acquired and conveyed land based on their own interests and their perceived interests of the other parties. This context provides an important framework for understanding broader influences in local land ownership histories.

Conservation organizations, environmental government agencies, and environmentalists have historically been concerned about responding to changes in private forestland ownership. The new era of private forestland ownership includes the rise of Timber Investment Management Organizations (TIMOs). These organizations are much more elusive than their historical industrial counterparts, which is concerning for conservation organizations who rely on responding to their competitors in an informed and strategic way. Conservation organizations are concerned with where and how much land TIMOs are acquiring and understanding how TIMOs contribute to the parcelization of the landscape. Parcelization and parcel ownership type have both been linked to changes in overall land cover and landscape condition (Haines, Kennedy, & McFarlane, 2011). Understanding how TIMOs fit into the historical context of land acquisition and ownership can provide a clearer picture of how TIMO land acquisition is similar to or different from other known ownership types (Donnelly & Evans, 2008; Haines, Kennedy, & McFarlane, 2011; L'Roe & Rissman, 2017; Zhang, Butler, & Nagubadi, 2012). The hemlock-hardwood forest region of Pennsylvania has historically been timbered by industrial forestland companies, and more recently, TIMOs. This region has a rich oil and timber ownership history that dates back to the early 1900s, which includes the establishment of the Allegheny National Forest in response to over extraction of timber resources. Connecting this ownership history with the state of TIMO current ownership could provide a more informed understanding to agencies that want to respond to TIMO ownership in a strategic manner.

Parcel boundary changes are both unique to the particularities of the region and are aligned with broader parcelization trends to varying degrees. Parcelization has increased through time in many parts of the United States, including counties in Minnesota, Wisconsin, and Indiana (Donnelly & Evans, 2018; Haines, Kennedy, & McFarlane, 2011; Mundell, Kilgore, & Snyder, 2010). However, subdivision, parcel consolidation, and parcelization type is often characteristic of specific changes in ownership and proximity to certain landscape features, and does not occur uniformly across a study site (Donnelly &

Evans, 2008; Haines, Kennedy, & McFarlene, 2011; L’Roe & Rissman, 2017; Mundell, Kilgore, & Snyder, 2010). Therefore, it is important to assess parcel changes at multiple levels (e.g., individual parcels, and among parcels) and to gain a better understanding of the factors (e.g., ownership and landscape patterns) that govern these changes.

The focus of this study is to understand how much land is under the management of or has been acquired by TIMOs, the types of agencies that previously owned this land, if parcel boundaries are changing along with this transition, and how this change relates to broader ownership and parcelization patterns. This will be accomplished through 2 research questions: 1. Are there common ownership and parcelization type histories specific to the parcels currently owned or managed by TIMOs? 2. How do the ownership and parcelization histories of land currently managed by TIMOs relate to broader ownership and parcelization trends? For research question one, a significant transfer of ownership between industrial and TIMO is expected between the 1978 and 1997 map years. Common parcel transfer histories are expected across parcels under TIMO ownership. Areas owned by or under the management of TIMOs may show a faster rate of parcelization or a common ownership transfer history and may therefore be high priority areas for conservation easements or fee simple acquisitions to prevent future subdivision or future transfer of ownership. For research question two, parcelization and parcel consolidation types are expected to be characteristic of specific changes in ownership transfers, particularly transfers from industrial to TIMO ownership. Parcelization is expected to increase at the level of the study site and the number of owners is expected to increase through time.

### **History of McKean County**

Forests cover roughly 58% of the 29.5 million acres in Pennsylvania, but used to cover about 90% of the state before colonial settlement (DCNR, 2010; USDA, 2016). Most of this forest is owned by private forest land owners and about 30% is owned by the public through state and federal agencies (USDA, 2016). The focus of this study is in McKean, County Pennsylvania. McKean County is located in northwest Pennsylvania and covers about 0.6 million acres, or 2% of the total state area (Encyclopedia Britannica, 2019). McKean County is part of the Allegheny Plateau ecoregion, which consists of a hemlock-hardwood forest (Whitney, 1990). This region has undergone changes in forest composition as a result of, or concomitant with, forest ownership trends.

Land ownership in McKean County has changed over the past century with the boom and bust of major oil and timber industries. Prior to colonization, the Native American Iroquois lived in northern Pennsylvania. In 1784, the Treaty of Fort Stanwix, also known as the “Last Purchase” was finalized and colonists forced the Iroquois out of the region (Encyclopedia Britannica, 2019). McKean County was then officially formed in 1804 (Encyclopedia Britannica, 2019). During this time, land in McKean County was cheap, and large companies as well as wealthy individuals began investing in timberland. Of these agencies and individuals were William Bingham and Holland Land Company (Painted Hills Genealogy Society, 2002). White pine (*Pinus strobus*) was harvested during this time to meet the demand of industry in Pittsburgh and other nearby cities. The trees were cut down and then shipped along the rivers downstream (Cox, 1984).

Starting in the mid-1800s, the construction of tanneries meant demand for eastern hemlock (*Tsuga canadensis*) bark, and logs were shipped via railroad (Cox, 1984). Wood chemical companies began to claim ownership in McKean County to meet the demand for charcoal and calcium acetate and utilized unwanted and left-over trees that were not of use to the tanneries and other lumber industries (McQuillen & Garvey, 1985). Timber was also owned by the pulp and paper industry. One of the major owners was the Hammermill Paper Company, which was then transferred to International Paper Company

in 1986 (Wall Street Journal, 1986). Hammermill Paper Company began timbering hardwood trees in the 1940s. This was possible because the company developed the neutracel process, which allowed for the processing of hardwood trees to make pulp (McQuillen & Garvey, 1985). In recent years, there has been a shift in ownership and management towards TIMOs due to shifting economic patterns (Binkley, 2007; Zhang, Butler, & Nagubadi, 2012). These companies advise and manage land for investors. This shift occurred partly because there was a push for investment companies to diversify their portfolios, and because timberland is a low risk investment (Binkley, 2007; Zhang, Butler, & Nagubadi, 2012).

Conservationists have responded to over-extraction of timber resources during the last century. By the beginning of the 1900s, much the over harvesting of forestland left few trees on the land. People familiar with the area termed the land “the Allegheny Brush-Patch” (Johnson & Govatski, 2013). This was a reality for many forested areas in the United States, which prompted the federal government to establish national forests and conservation corps. As a result, the Allegheny National Forest, which is across much of western McKean County, was formed in 1923 (Johnson & Govatski, 2013). However, the establishment of the Allegheny National Forest did not mean an end to all harvesting and extraction of resources. The Allegheny National Forest was set up to be a “land of many uses”, and harvesting still occurred (Che, 2012).

### **Parcelization Defined**

A parcel represents the extent to which an individual or agency owns real estate. Parcelization can be defined as an increase in subdivision of parcels over time. Parcelization is subjective and difficult to define, and changing the characterization can severely impact the results of a study (Kilgore et al., 2012). Donnelly and Evans (2007) characterized parcelization by tracking individual parcels (called “parent” parcels) and their subdivisions (called “child” parcels) through time, and then categorizing the parcel changes by their range ratio, which is the likeness of the area of each subdivision to other subdivisions and to the parent parcel, and by the number of subdivisions. Donnelly and Evans (2007) then tracked the number of parcelization types between years and assessed whether certain parcelization types were occurring more or less than they expected. Mundell et al. (2010) tracked parcels from parent to child for a study site in Minnesota. The researchers recorded the total number of splits between 1999 and 2006 and found that the most common subdivision was a split into two parcels. Kilgore et al. (2012) compared many parcelization metrics to determine how these metrics influence results. The researchers determined that each metric showed different levels of parcelization, and that simply comparing mean acreage size does not capture the full story. Although hesitant to recommend any metric, they erred on the side of using what they determined as the “Adjusted Mean” metric to determine parcelization across a study site, which is “(% of private forest land in parcels below a parcel size threshold) x (number of private forestland parcels)”. They used 40 acres as the threshold cut off for which a parcel can be considered as an indicator of a parcelization landscape because this is the minimum size of which industrial timbering can occur according to the Public Land Survey System, one of the first U.S. survey systems.

### **Effects of Parcelization on Landscape Condition**

Parcel boundaries and parcelization have shown to be strongly correlated with land use patterns (Benduch, 2019). Parcelization occurs for a variety of reasons, but can occur when there is an intention of developing one of the subdivided parcels (Mundell et al, 2010). Forestland parcels owned by families are often subdivided when the owner dies and heirs inherit the land (Mehmood & Zhang, 2001). Additionally, subdivision of parcels in rural areas often occurs on parcels that are adjacent to existing road or bodies of water (L’Roe & Rissman, 2017; Mundell et al, 2010). Studies indicate a general trend of increasing parcelization over time in forested areas, however, some studies show no trend of parcelization

or parcel boundary changes occurring in specific areas (Mundell et al., 2010). Parcelization can influence the ecological condition of the landscape. Development activities are more likely to be associated with parcelization (Mundell et al., 2010). Forest fragmentation can occur due to an increase in diversity of management styles and development as parcels become increasingly subdivided (Haines, Kenney, & McFarlane, 2011).

### **Forest Land Ownership Categories Explained**

Similar to parcelization, ownership type can be difficult to define and can change the results of the study depending on the definitions. Forestland ownership can be categorized in a variety of ways, but the simplest way is to differentiate between public and private ownership. Public ownership can then be broken down into different types including state, federal, municipality, etc. (Jin & Sader, 2006). Private ownership can be broken down into industrial owner TIMOs, Real Estate Investment Trust (REIT), non-industrial private forestland owner (NIPF) (Jin & Sader, 2006). However, categorizing ownership can be complicated, and questions can arise about what is private and what is public. Parts of public land can sometimes be managed by private companies and public land can also have some areas restricted to the public to protect endangered species (Weiss et al., 2017).

### **Prioritizing Conservation Based on Parcelization Histories**

Conservation organizations often weigh many different ecological, social, political, and economic factors when determining where to prioritize efforts. These multiple and often competing factors add to the complexity of where, when, and how to conserve. Researchers have used algorithms to weigh these competing priorities and identify places on the landscape that result in the best return on investment for conservation (Thiel, Cho, & Armsworth, 2016; Cho et al., 2019, Wilson, Carwardine, & Possingham, 2009). Wilson, Carwardine, & Possingham, 2009 used a logical decision-making model to set up a framework for determining the overall costs and benefits of pursuing certain conservation projects over others. These models first require knowledge and data about the landscape in question.

Determining land use patterns, such as ownership management styles, could add another important element to a prioritization model (Wilson, Carwardine, & Possingham, 2009). Larger parcels often have a higher return on investment for conservation (Thiel, Cho, & Armsworth, 2016; Cho et al., 2019). Thiel, Cho, & Armsworth (2016) found that protecting larger parcels resulted in a “greater mesh size per dollar” than protecting smaller parcels. Cho et al. (2019) had similar results, but found that parcel size was not the only, and in some cases not even the greatest, factor in high return on investment. Levin & Nainggolan (2016) studied scrub occurrence in grassland areas of Denmark, and found that smaller parcel sizes resulted in higher levels of scrub area when compared to larger parcels.

Parcelization often does not occur uniformly spatially and temporally across a study site. A parcel-based density analysis protocol (P-DAP) was first developed by Thomas et al. (2009) and then used to determine temporal changes in parcelization by Salinas (2016). The centroid of each parcel is created and then point densities are generated across a raster. This requires the selection of a raster grid cell size and a search radius. Salinas (2016) then subtracted the raster layers between each year to determine temporal hotspots of parcelization.

## **Methods**

### **Data - Maps**

A series of tax and boundary maps provided by the McKean County Assessment Office were gathered, including years 1876, 1930, 1934, 1942, 1956, 1997, 2007 and 2019. 1978 and 1986 plat maps

were obtained from Rockford Map Publishers. Other maps are available in the Pennsylvania State Archives including from 1817, 1856, and 1876 (Table 1). The land was first surveyed in 1817 by John Whitefield and other surveyors, and a map was drawn which included the county and township boundaries (Pennsylvania State Archives). The next survey was completed in 1856. The county was divided up into uniform rectangular warrants, and major land owners were identified for large portions of the county (Library of Congress; Pennsylvania State Archives). The county map was drawn again in 1876, and included land owner names for each warrant to accommodate a larger number of owners (Pennsylvania State Archives). Another survey was completed in 1930 and includes witness trees and a record of when each warrant was purchased, however, this ownership map does not include parcel boundaries, and cannot be used to assess parcelization. In 1934, the county maps were drawn once again, this time with the inclusion of lots within warrant boundaries and recorded acreage within each lot. The 1946 map includes both surface and subsurface owners, as well as oil and gas well locations. Tax parcel maps with the parcel identification number (PIN) system were first drawn in the 1956. Boundaries were then updated by hand on the 1956 map up until 1997. A geographic information system (GIS) was established in the McKean County office in the early 21st century, and the vector-based parcel boundaries were drawn from the 1997 tax parcel maps.

Map Year	Source	Ownership Information	Parcel Boundary Information	Used in Analysis
1817	Pennsylvania State Archives	No	No	No
1856	Pennsylvania State Archives	Warrant boundary ownership	No	No
1876	Pennsylvania State Archives	Warrant boundary ownership	No	No
1930	McKean County	Warrant boundary ownership	No	No
1934	McKean County	Yes – surface & subsurface	Yes	Yes
1942	McKean County	Yes – surface & subsurface	Yes	No – information missing from significant portion of the county
1956	McKean County	No	Yes	No
1978	Rockford Publishing	Yes	Yes – except for parcels with congruent ownership	Yes
1986	Rockford Publishing	Yes	Yes – except for parcels with congruent ownership	Yes
1997	McKean County	No	Yes	Yes
2007	McKean County	Yes	Yes	Yes
2019	McKean County	Yes	Yes	Yes

**Table 1.** Descriptions of surveys used for analysis. Included is the map year, source of data, whether or not ownership and parcel boundary information is present, and whether or not the data was used for analysis.

## Georeferencing Maps

The parcel maps are in jpeg format, excluding the 2007 and 2019 tax parcels. ArcGIS Pro software was used to georeference the jpeg maps. The 2019 tax parcel boundaries, along with the 2003-2008 PA MAP aerial imagery, vector street data, warrant boundaries, township boundaries, and county boundary were used as references for georeferencing, assuming the 2019 tax parcel layer is showing the most accurate representation of ownership. The appropriate projection was selected according to the map scale. At least 5 control points were used across each map. The 1934 surveys included separate jpegs for

each warrant, and a reference jpeg for each township. The 1956 surveys were divided into jpegs that covered multiple warrant boundaries, and included a reference jpeg for each township. The 1978 and 1986 surveys included jpegs and a reference jpeg for the county. The 1997 survey included hand drawn updates based on the 1956 survey, and included a reference jpeg for each township. Reference jpegs were georeferenced first for each map year, and then jpegs were georeferenced. The 2007 vector polygon layer was already digitized.

### **Parcel Digitization**

Vector based polygons were created for each of the georeferenced maps. A vector layer was created for each map year, and the 2019 polygon layer was appended to each. Parcels were then adjusted to reflect the shape in each map year. Snapping was used during polygon creation and adjustment to ensure that there was no overlap between polygons. In cases where there was limited or unclear data, the parcel boundary was left out of that map year, and analysis occurred between the map years that had sufficient data. The 1942 data was left out of the analysis because data was not available for a sufficient portion of the county. An “acreage” field with a double type was then added and calculated for each map year.

### **Ownerships Identified - 2019**

The 2019 ownership types identified for analysis include influential players in the landscape that provide sufficient comparison to TIMOs. State, federal, industrial, and TIMO owners were identified as important players that currently and historically own most of the forestland in McKean County. Two key industrial owners were identified, each having an important an influential history in the region – Collins Pine Company and Seneca Resources. Each type was categorized in the 2019 parcel layer for all parcels above 10 acres, which was an acreage threshold chosen as the minimum requirement for significant importance in the context of timbering and forestland protection. The Collins Pine Company and Seneca Resources ownerships were the easiest to identify because the ownership names are clearly stated in the parcel data. The state and federal ownership types were the second easiest to identify, each including some keywords such as “Commonwealth”, “Federal”, “Department”, “United States”, “Pennsylvania”, “PA”, and “USA”. The most difficult ownerships to identify were the TIMOs. These ownership names often have the keyword “Investment” or “Insurance” in their company name, but not always. Research needed to be done for many of the TIMO company names before they could be properly labeled as TIMOs. Often if there was not much information online, it was a good indication that the owner was a TIMO because many TIMOs do not openly display information to the public.

### **Ownership Identified – 2007, 1997, 1986, 1978, 1956, and 1934**

Working backwards through time, ownerships were entered for each map year. Some map years had significant gaps in data. The 2019 parcel layer included the three previous owners and dates acquired and transferred, along with the deed book and page number documenting this transfer. This information was used to fill in gaps in ownership information where possible. If it was not possible to find the ownership information without significant research, the ownership was left blank. The 1934 map year includes both surface and subsurface ownership. The surface ownership was identified for this map year and entered for each parcel. The 1956 and 1997 ownership information were not available. This information could sometimes be found in the 2019 parcel layer attribute table, which included the three previous owners for each record and the date of conveyance. The 1978 and 1986 surface ownership information were available for each map year. The 2007 vector layer was used as a reference for entering ownership information for that year. The 2019 ownership information was standardized for that ownership year.

## Connecting Parcel Changes Through Time

The concept of “parent” and “child” parcels from Donnelly & Evans (2006) was used to analyze parcelization through time. However, for this study, instead of tracking the parcel lifecycle from the earliest map year to the latest map year, each parcel was tracked from the latest map year to the earliest map year. During the vector creation process, it was identified that many parcels were actually consolidated over time - almost a reverse parcelization. This resulted in a need to reverse the processed used in many parcelization studies; the 2019 parcels became the “parent” parcels and subsequent years were the “child” parcels. Parcels from each map year were connected to the adjacent map year by spatial selection. If the parcel’s center was in or was identical to the previous map year, it was selected as the “child” parcel. This process was then manually evaluated and updated to exclude and include parcels that were unintentionally missed or selected.

## Parcel Changes - Area

Parcel changes were identified or each ownership type (Federal, State, TIMO, Collins Pine Company, and Seneca Resources) working backwards through time. Parcel acreage size was added and graphed in a percent normal distribution graph in excel using the =NORM.DIST function, which uses value, average, standard deviation, and cumulative set to FALSE. This was done in order to analyze the distribution of parcel sizes in relation to the average and standard deviation across map years. Graphs were created for each ownership type for 1934, 1986, and 2007, and an overview graph was created for 2019 and 1934.

## Parcel Changes – Perimeter / Area

Perimeter over area calculations can show both differences in size as well as complexity of shape. Higher values indicate smaller parcels and less complex shape, and lower values indicate larger parcels with a more complex shape. Perimeter over area was calculated for 1934 and 2019 parcels, and then displayed in a percent normal distribution graph as described above in “Parcel Changes – Area”.

## Ownership Histories

Ownership histories summary bar charts were created for each ownership types for 1934, 1986, and 2007. This was done by creating bar chart in ArcGIS Pro using the sum of acreages grouped by ownership, and exporting to excel. Ownership types under a certain acreage threshold were grouped together for the graphs in order to display the information in a readable way. Maps were created to reflect each of the graphs to visually show the parcel changes.

## Top Ownership Exchanges

The Spatial Join tool was used to combine parcel layers from 1934 to 2019, with a many to one join, and with a merge rule of “first” for each of the fields in Field Map. The 2007 parcel layer was joined to the 2019 parcel layer, resulting in a combined layer “spatial\_join\_2019\_2007”. The 1997 parcel layer was then joined to “spatial\_join\_2019\_2007”, resulting in a combined layer “spatial\_join\_2019\_2007\_1997”. This process was repeated until all layers from 1934 to 2019 were combined into one layer, “spatial\_join\_final”. Six text fields were then added to spatial\_join\_final to capture the ownership exchanges from one owner to the next – “one\_two”, “two\_three”, “three\_four”, “four\_five”, “five\_six”, “six\_seven”. Calculate field was then used to execute Python code that takes the first two values found in the list of fields, adds them to a list as long as they are not already in the list and not a blank or null value, and then creates a string that was added as the value (Figure 1).



```

Concat(!Owner_2019!, !Owner_2007!, !Owner_1997!, !Owner_1986!, !Owner_1978!, !Owner_1956!, !Owner_1934!)

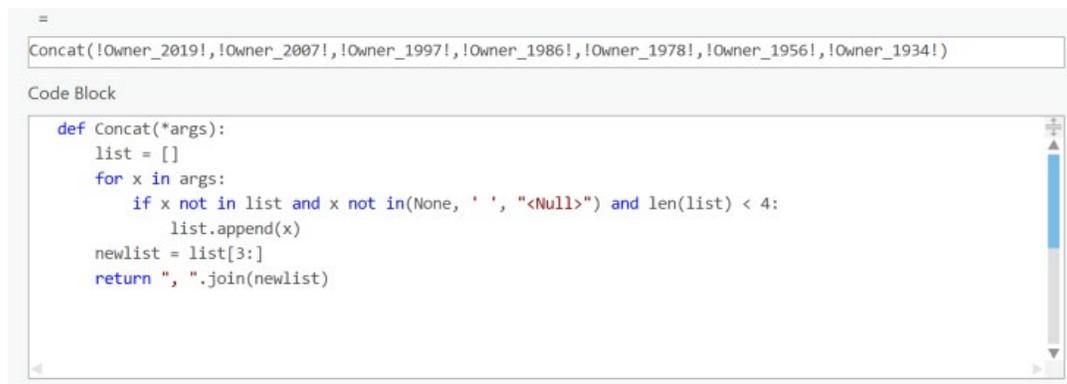
Code Block

def Concat(*args):
    list = []
    for x in args:
        if x not in list and x not in(None, ' ', "<Null>") and len(list) < 2:
            list.append(x)
    return ", ".join(list)

```

*Figure 1. Python code used to add the first and second owners to the “one\_two” field.*

To populate the “two\_three” field, a similar Python code was used that added the first three values to a list, and then a new list was created that deleted the first value, leaving only the second and third values (Figure 2). This process was then repeated for all other fields (“three\_four”, “four\_five”, “five\_six”, and “six\_seven”). The final result was a list of all ownership exchanges, and owners that held ownership through the 1934 to 2019 period. This final table was then exported to an Excel file, and all ownership exchanges were added to a single column along with acreages in an adjacent column. This Excel file was then added to ArcGIS Pro and exported as a table. The Summary Statistics tool was then used to group the ownership exchanges and summarize the acreage. The result was then added to a bar chart to show top ownership exchanges.



```

Concat(!Owner_2019!, !Owner_2007!, !Owner_1997!, !Owner_1986!, !Owner_1978!, !Owner_1956!, !Owner_1934!)

Code Block

def Concat(*args):
    list = []
    for x in args:
        if x not in list and x not in(None, ' ', "<Null>") and len(list) < 4:
            list.append(x)
    newlist = list[3:]
    return ", ".join(newlist)

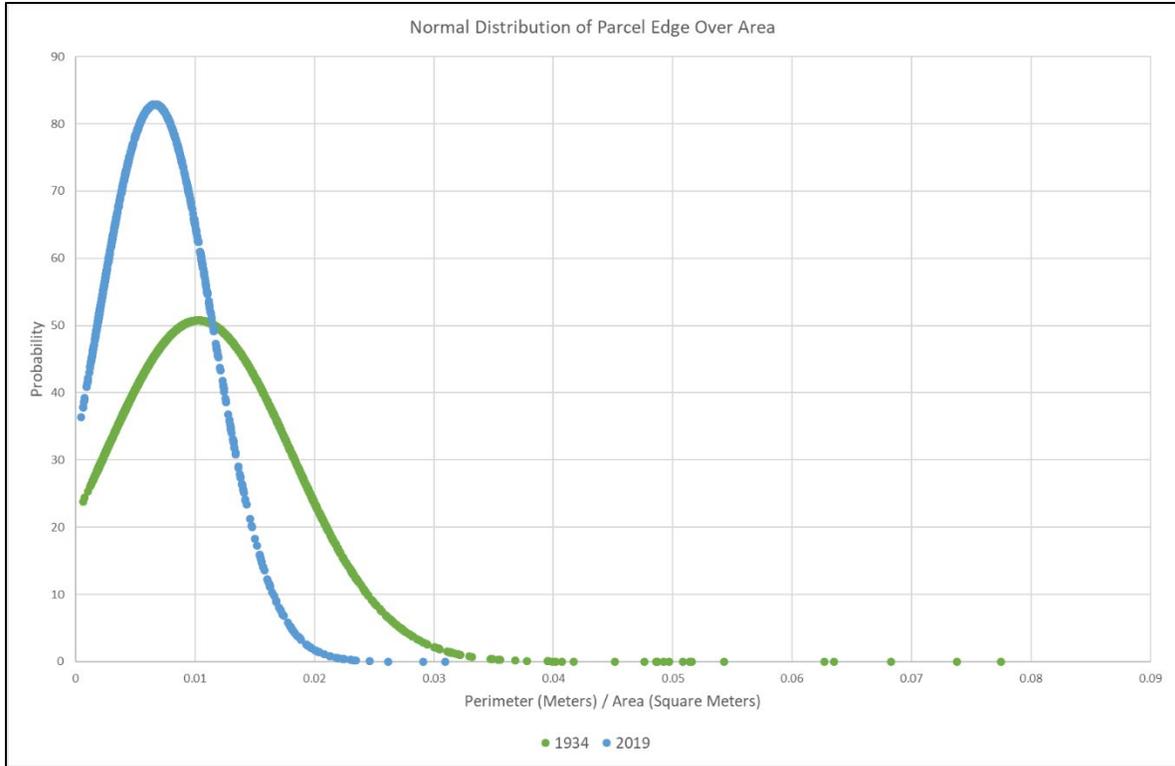
```

*Figure 2. Python code used to add the second and third owners to the “two\_three” field.*

## Results

### Parcel Area Changes Overview – 1934 Compared to 2019

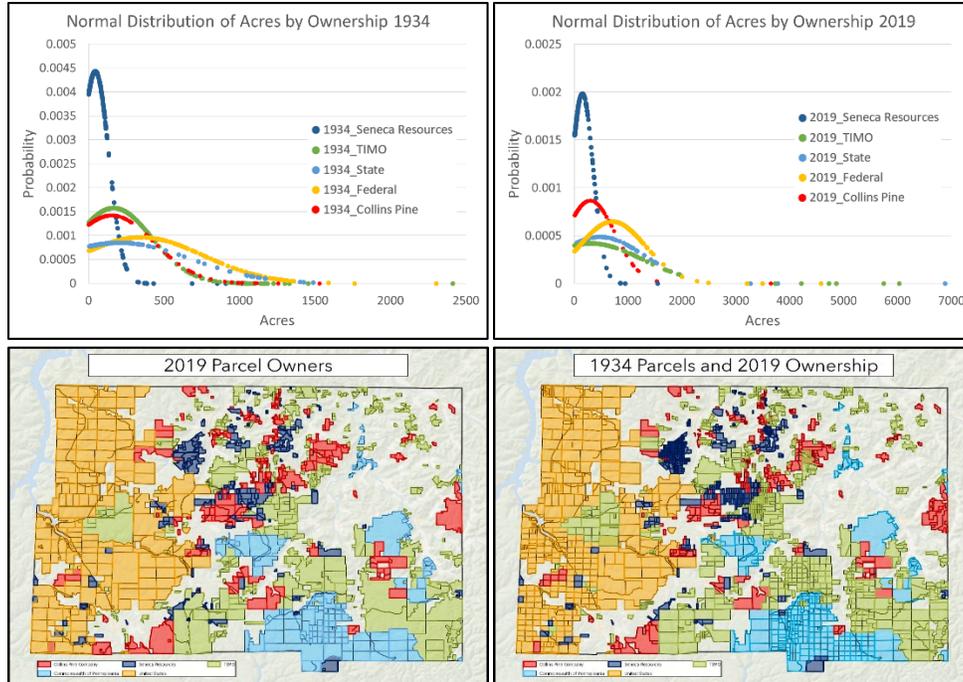
The 1934 parcels tended to be smaller and less complex, with an average perimeter to area ratio of 0.0103, and a standard deviation of 0.0081. The 2019 parcels tended to be larger and more complex, with an average perimeter to area ratio of 0.0066 and a standard deviation of 0.00481 (Figure 3).



*Figure 3. Normal distribution of perimeter to area ratio for the 2019 and 1934 parcels.*

**Ownership Change Overview – 1934 Compared to 2019 per Ownership Type**

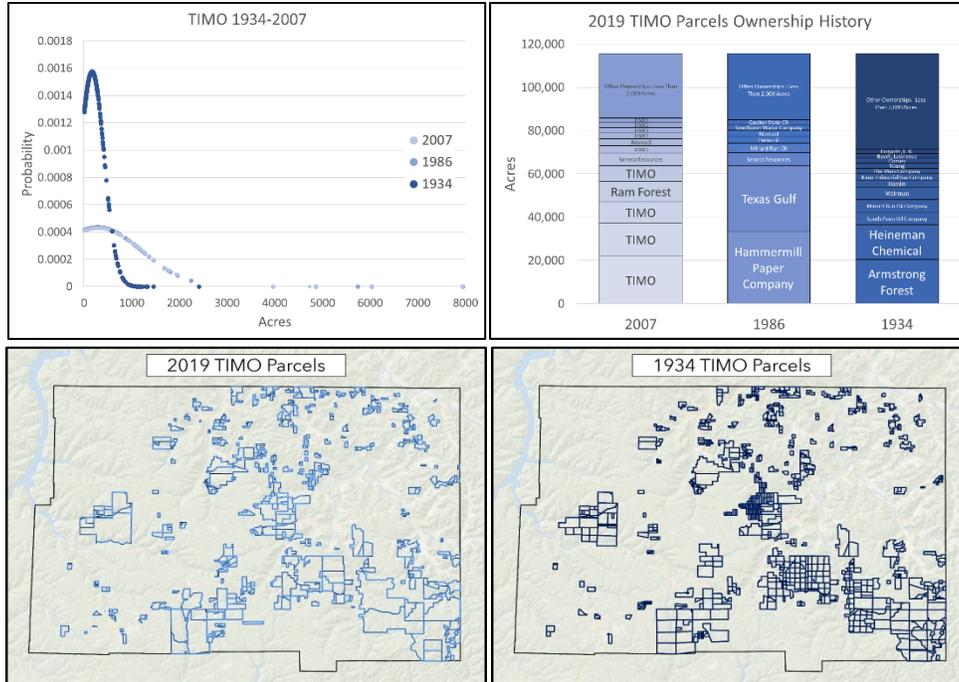
Parcel size increased over time for all ownership types. The Seneca Resources parcels were the smallest in both 1934 and 2019, with an average of 152.05 +/- 200.85 acres in 2019 and an average of 43.19 +/- 89.96 acres in 1934. The federally owned parcels changed the least, with an average of 708.37 +/- 615.68 acres in 2019 and an average of 347.31 +/- 413.53 acres in 1934. The Collins Pine Company parcels moderately changed, with an average of 296.75 +/- 459.87 acres in 2019, and an average of 151.89 acres and a standard deviation 280.63 acres in 1934. The state-owned parcels moderately changed with an average of 479.05 +/- 817.48 acres in 2019 and an average of 205.44 +/- 468.71 acres in 1934. The TIMO parcels changed the most, with an average of 314.86 +/- 946.31 acres in 2019, and an average of 165.58 +/- 253.1 acres in 1934 (Figure 4).



**Figure 4.** Normal distribution of parcel size for each ownership type in 2019 (top left), normal distribution of parcel size for each ownership type in 1934 (top right), map of parcels per ownership type in 2019 (bottom left), and map of parcels per ownership type in 1934 (bottom right).

**Changes in TIMO Parcels and Ownership History**

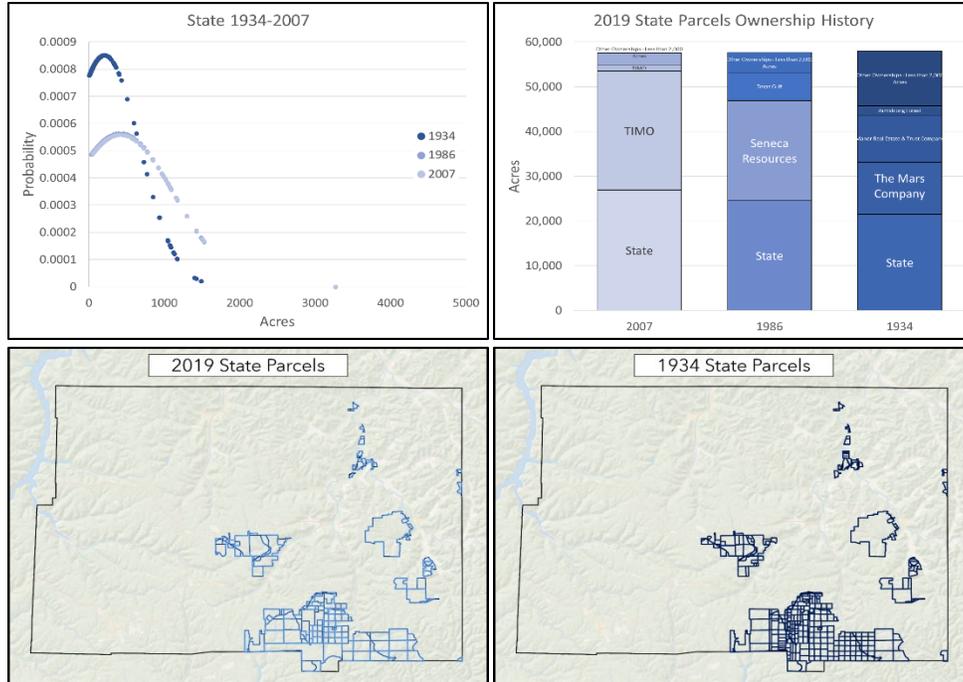
The TIMO parcel sizes change dramatically between 1934 and 2019, and there was a wider distribution of values in 2019. The average parcel size in 1934 was 165.58 +/- 253.09 (+/- 1 SD) acres, compared to the average parcel size in 2019 of 314.86 +/- 949.31 (+/- 1 SD) acres. Top owners in 1934 include The Armstrong Forest Company, Heineman Chemical, South Penn Oil Company, and Minard Run Oil Company. Top owners in 1986 include the Hammermill Paper Company, The Texas Gulf & Sulphur Company, and Seneca Resources. Top owners in 2007 include 4 different TIMOs, Ram Forest, and Seneca Resources (Figure 5).



**Figure 5.** Normal distribution of parcel size for 1934, 1986, and 2007 for TIMO parcels (top left), bar chart of top owners and acres owned in 1934, 1986, and 2007 (top right), map of 2019 TIMO parcel ownership (bottom left), and map of 1934 TIMO parcels (bottom right).

### Changes in State Parcels and Ownership History

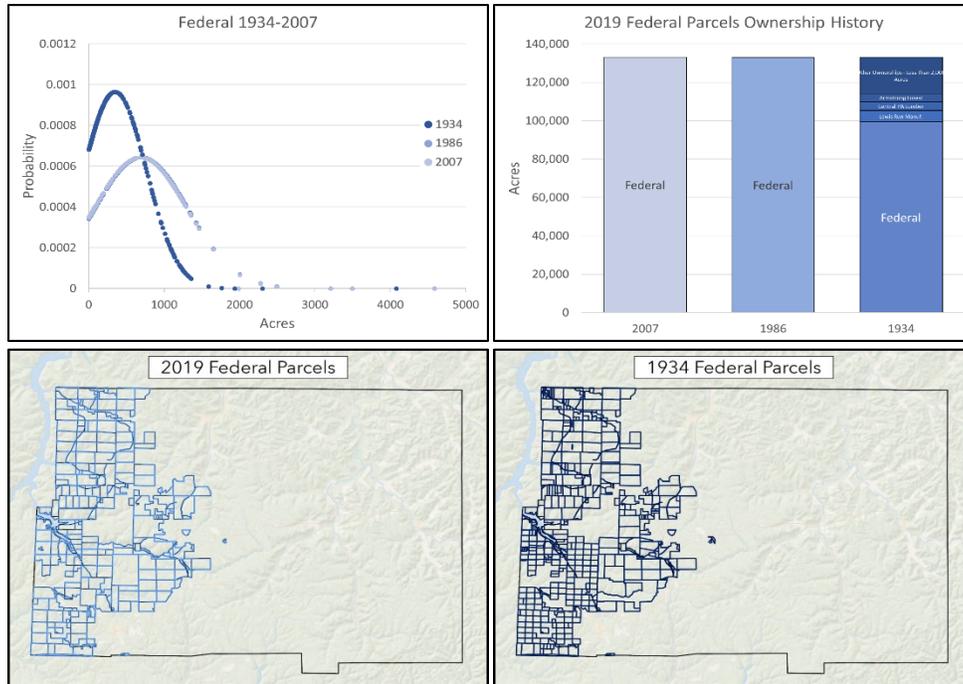
The state-owned parcels changed moderately between 1934 and 2019. The average parcel size in 1934 was 205.44 +/- 468.70 (+/- 1 SD) acres. The average parcel size in 2019 was 479.05 +/- 817.48 (+/- 1 SD) acres. Top owners in 1934 include Commonwealth of PA, The Mars Company, and Manor Real Estate & Trust Company. Top owners in 1986 include Commonwealth of PA, Seneca Resources, and Texas Gulf. Top owners in 2007 include Commonwealth of PA and a TIMO (Figure 6).



**Figure 6.** Normal distribution of parcel size for 1934, 1986, and 2007 for state parcels (top left), bar chart of top owners and acres owned in 1934, 1986, and 2007 (top right), map of 2019 state parcel ownership (bottom left), and map of 1934 state parcels (bottom right).

### Changes in Federal Parcels and Ownership History

The federally owned parcels changed the least amongst the ownership types, but consolidation still occurred between 1934 and 2019. The average parcel size in 1934 was 347.31 +/- 413.53 (+/- 1 SD) acres. The average parcel size in 2019 was 708.36 +/- 615.68 (+/- 1 SD) acres. Top owners in 1934 include United States, Lewis Run Manufacturing, Central Pennsylvania Lumber, and The Armstrong Forest Company. The United States owned almost exclusively all land in 1986 and 2007 (Figure 7).

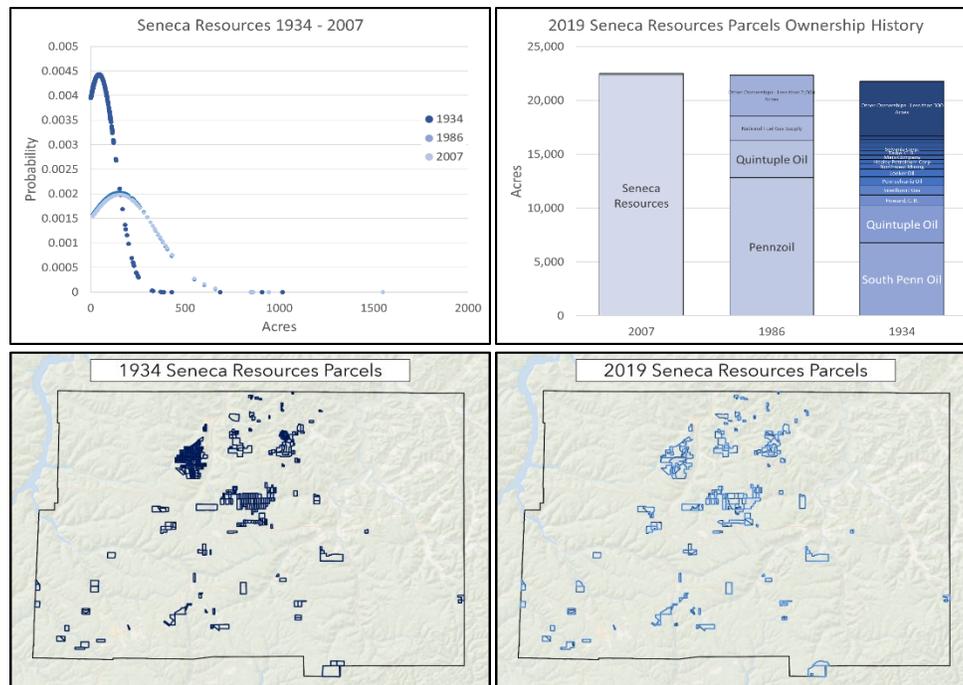


**Figure 7.** Normal distribution of parcel size for 1934, 1986, and 2007 for federal parcels (top left), bar chart of top owners and acres owned in 1934, 1986, and 2007 (top right), map of 2019 federal parcel ownership (bottom left), and map of 1934 federal parcels (bottom right).

**Changes in Collins Pine Company Parcels and Ownership History**

The Collins Pine Company parcels did not change much in size between 1934 and 2019. The average parcel size in 1934 was 151.89 +/- 280.63 (+/- 1 SD) acres. The average parcel size in 2019 was 296.75 +/- 459.88 (+/- 1 SD) acres. The Collins Pine Company parcels had the most variety and number of owners in 1934. Top owners in 1934 include The Otto Chemical Company, PA Wood Products, J. W. Matthews, The Northwest Mining Company, The Heineman Chemical Company, Bradford Wood, Benjamin Haywood, C. R. Dolley, James Connelly, and Crystal Springs Water. The Collins Pine Company then almost exclusively owned all acreage in 1986 and 2007, followed by The Quaker State Oil Company in 1986 (Figure 8).



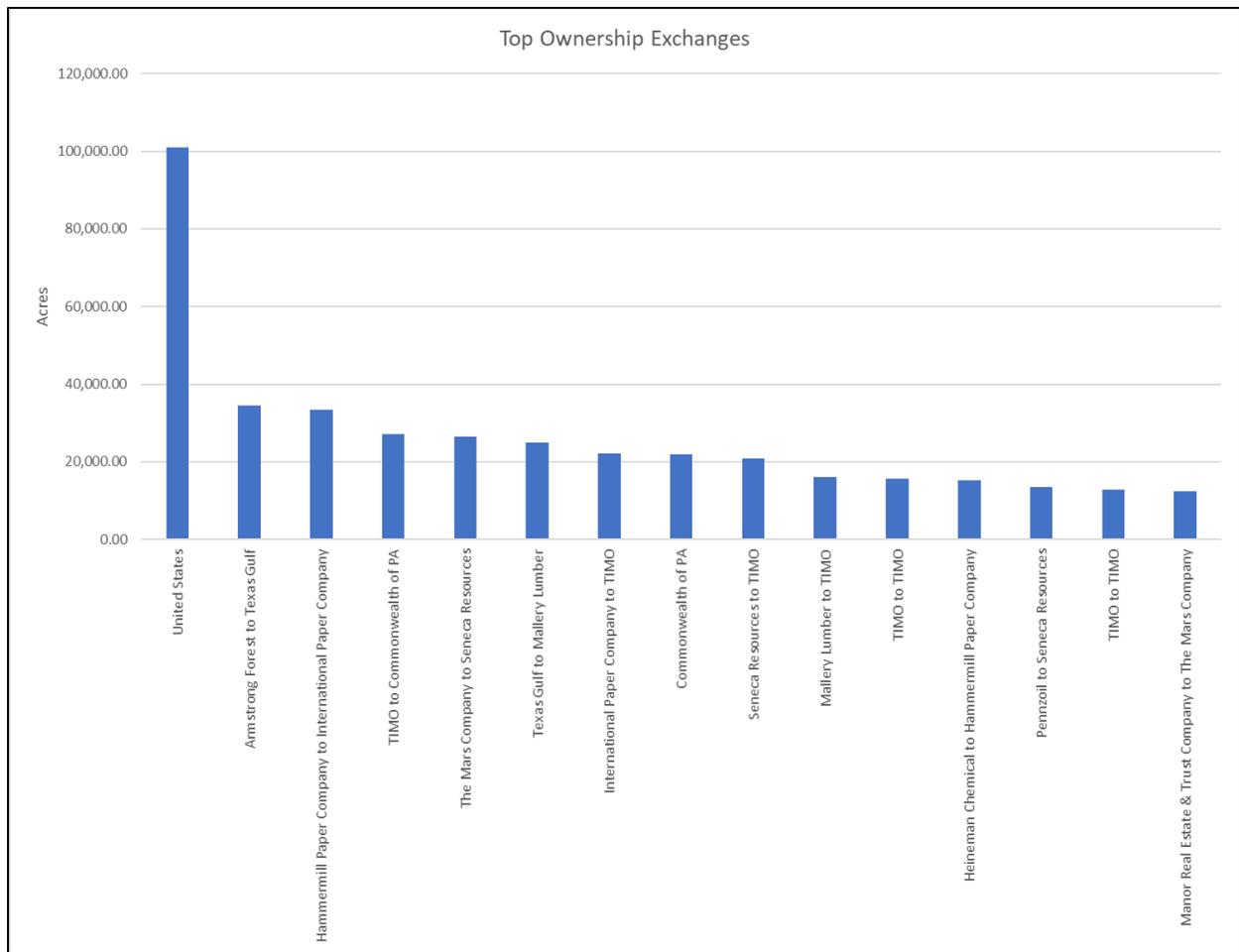


**Figure 9.** Normal distribution of parcel size for 1934, 1986, and 2007 for Seneca Resources parcels (top left), bar chart of top owners and acres owned in 1934, 1986, and 2007 (top right), map of 2019 Seneca Resources parcel ownership (bottom left), and map of 1934 Seneca Resources parcels (bottom right).

### Top Ownership Exchanges

The ownership exchanges captured include one owner to the next as well as owners that held ownership through the 1934 to 2019 time period. The United States acquired 100,978.49 acres by 1934 and held that land without conveyance until 2019. The next highest exchanges were Armstrong Forest to Texas Gulf and Hammermill Paper Company to International Paper Company with 34,589.38 acres and 33,500.86 acres exchanged respectively. The state also held 21,978.67 acres throughout the 1934 to 2019 time period, and acquired 27,056.39 acres from a TIMO.

The top 15 ownership exchanges can be grouped into four waves throughout the 1934 to 2019 period. The first wave of industrial owner exchanges between 1934 and 1978 is represented in the Armstrong Forest to Texas Gulf (34,589.83 acres), The Mars Company to Seneca Resources (26,458.09 acres), Heineman Chemical to Hammermill Paper Company (15,297.96 acres), and Manor Real Estate & Trust Company to The Mars Company (12,344.97 acres) exchanges. The second wave of industrial owner exchanges between 1978 and 2007 is represented in the Hammermill Paper Company to International Paper Company (33,500.86 acres), Texas Gulf to Mallery Lumber (24,989.77 acres), and Pennzoil to Seneca Resources (13,480.86 acres). The third wave of industrial owner to TIMO exchanges between 1986 and 2019 is represented in the International Paper Company to TIMO (22,234.15 acres), Seneca Resources to TIMO (20,843.20 acres), and Mallery Lumber to TIMO (16,168.84 acres) exchanges. Finally, the third wave of owner exchanges between TIMOs and other TIMOs, including a 12,899.83 acres exchange and a 15,692.42 acres exchange (Figure 10).



**Figure 10.** Top ownership exchanges between 1934 and 2019, including parcels acquired and held throughout that time period.

## Conclusion

The focus of this study was to characterize Timber Investment Management Ownership acquisitions in the context of broader ownership trends using the study site McKean County, Pennsylvania. This was accomplished through 2 research questions: 1. Are there common ownership and parcelization type histories specific to the parcels currently owned or managed by TIMOs? 2. How do the ownership and parcelization histories of land currently managed by TIMOs relate to broader ownership and parcelization trends?

Consolidation occurred across the study site amongst all ownership types between 1934 and 2019, and parcel shape became more complex. The 2019 TIMO parcels showed the highest change in parcel size between 1934 and 2019. This was followed by Seneca Resources, The Collins Pine Company, and the state-owned parcels. The federally owned parcels showed the least amount of change in area. This could be because most of the federally owned parcels were acquired on or before 1934 and stayed in federal ownership. As other private owners came and went, the federal ownership remained the same and for the most part, so did the parcels. Consolidation between 1934 and 1956 could have been a result of both policy and changes in the timber industry.

Each ownership type had different ownership histories. The TIMO parcel ownership history included top industrial owners – the Armstrong Forest Company, the Hammermill Paper Company, and Texas Gulf & Sulphur Company. The state ownership history included ownership that dates back to 1934, and other parcels acquired from both TIMO and industrial owners. The federally owned parcels included a significant amount owned and kept throughout the time period, and others acquired from The Armstrong Forest Company and other industrial owners. The Seneca Resources parcels were previously owned by a variety of oil companies, including the South Penn Oil Company, Quintuple Oil Company, and Pennzoil. The Collins Pine Company has ownership that dates back to 1934, and other parcels were acquired from a variety of both individual and industrial owners.

There were some significant ownership exchanges. The United States owned and retained the largest amount of land out of all the ownership types. This was followed by two industrial ownership exchanges, between The Armstrong Forest Company and Texas Gulf & Sulphur, and the Hammermill Paper Company to The International Paper Company. Both of these industrial exchanges are good examples of large shifts in ownership, potentially as a result of changes in the market, resource depletion and emergence, and innovative industrial processes.

## **Discussion**

The goal of this project was to characterize a quite complex history of land ownership in the Allegheny Plateau ecoregion using the study site McKean County, Pennsylvania in order to understand how Timber Investment Management Organizations (TIMOs) fit in to this picture. Many forces are a play when it comes to changes in land ownership – political, economic, social, ecological, changes in industry, and historical impact all have a role. To add to this complexity, survey methods and ownership names are not uniform across map years, and need to be uniform in order to perform any type of analysis. This posed a challenge, which resulted in a need to distill the study focus. This was done by focusing on significant ownership types, and parcels above 10 acres. However, this still required a lot of data processing before any analysis could occur. In future studies, it is advised to start with a sample selection of parcels at the county level, or develop a way to automate the georeferencing and vector creation process.

There is a great opportunity to further characterize this rich and complex timber ownership history. First, adding on even earlier surveys, including the post-revolutionary war allotments, would round out the story of post-colonial ownership. Many of the parcels reflect how they were surveyed in 1934, and it would be valuable to analyze similarity in boundaries shared and the impact of the original survey on overall distribution and characteristics of parcels. Adding other neighboring county parcel histories in the Allegheny Plateau eco-region would be valuable to compare to McKean County and understand broader parcel and ownership similarities and differences. Finally, adding on other ownerships and types not added in this study, including other industrial owners and municipalities, may show a wider variety of ownership histories.

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