

GISC 6387 PROJECT: PREDICTING OIL WELL YIELDS IN RUSSIA

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PROJECT PURPOSE

Predict the yield of oil wells in Russia based on their similarity to other wells with known production.

REVIEW OF LITERATURE

- Petroleum resource modeling
- ❖Geology of oil fields
- Soviet infrastructure

REVIEW OF LITERATURE: USGS

- United States Geological Survey
- 2000 World Petroleum Assessment
- Worldwide oil and natural gas production capacity
- Methodology [Charpentier and Klett (2005)]
- Geological factors
- Exploration history
 - *Larger accumulations generally found earlier, but
 - *Economic, technological, and political factors can also affect exploration trend

REVIEW OF LITERATURE: HAMIDA, ET AL. (2017)

- Explores variety of geometry-based optimization approaches for well placement in oil fields
- Measurement for quantitative similarity between wells
- ❖ Journal of Petroleum Science and Engineering

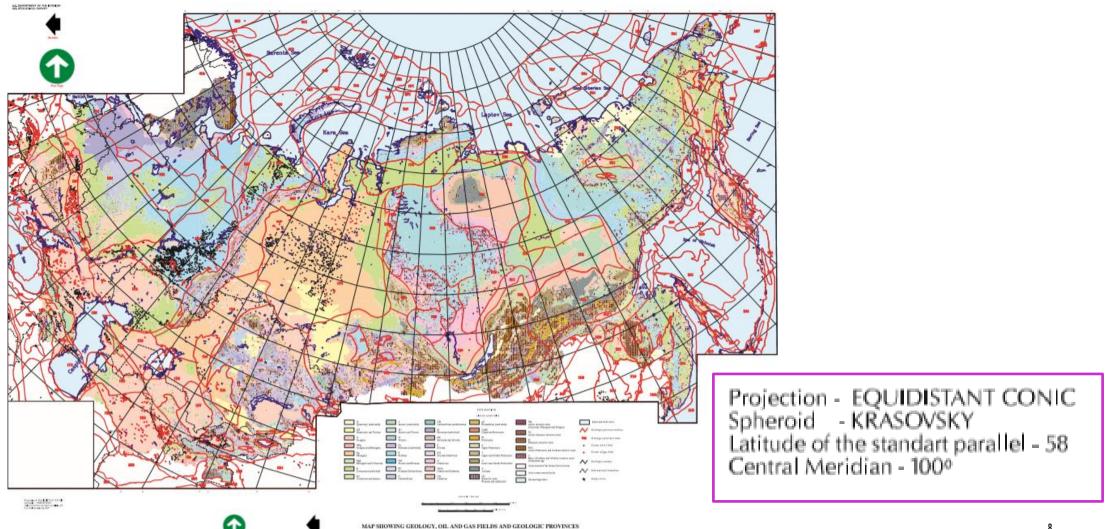
REVIEW OF LITERATURE: OTHER PAPERS

- Ivanov et al. (2018). The main factors affecting the distribution of oil fields in the West Siberian Platform.
- Proximity to Triassic rifts
- Thickness and geological age of the basement
- ❖ Campbell (1968). Economic Reform in the USSR.

STUDY AREA AND DATA SOURCES: USGS

- *USGS assessment of oil production capacity of oil fields in Former Soviet Union
- *Map to a shapefile of geological provinces

STUDY AREA AND DATA SOURCES: USGS

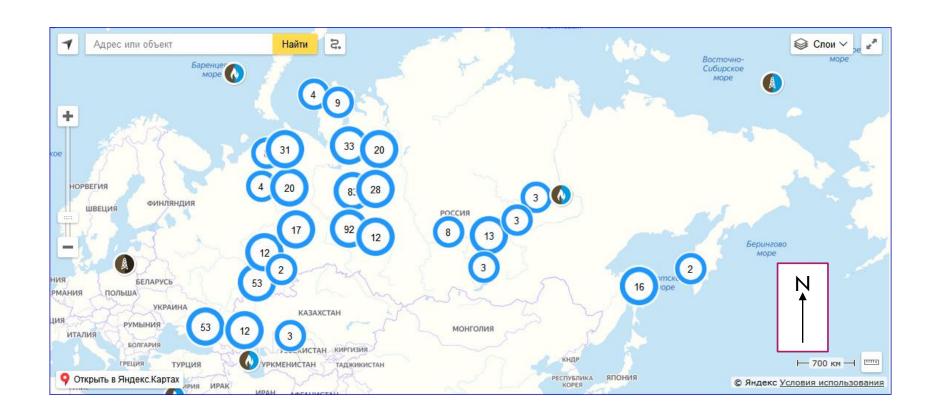


STUDY AREA AND DATA SOURCES: USGS

Quaternary (undivided)	J Jurassic (undivided)	CD Carboniferous and Devonian		pC Precambrian (undivided)	::::::	TKi Acidic intrusive rocks		Lakes and wide rivers
QT Quaternary and Tertiary	JTr Jurassic and Triassic	D Devonian (undivided)		CmPt Cambrian-Proterozoic	::::::	Creteceous, Paleogene and Neogene Mi Acidic Mesozoic intrusive rocks	/	Geologic province outline
N Neogene	Tr Triassic	DS Devonian and Silurian		Pt Proterozoic		Pi Paleozoic intrusive rocks	7203	Geologic province code
NPg Neogene and Paleogene	Pz Paleozoic (undivided)	S Silurian		Z Upper Proterozoic	:::::	PtAi Acidic Proterozoic and Archem intrusive rocks	•	Center of oil field
Pg Paleogene	P Permian	SO Silurian-Ordovician		Y Upper and Middle Proterozoic	::::::	ii Basic, Ultrabasic and Alkaline intrusive rocks	•	Center of gas field
PgK Paleogene and Cretaceous	TYP Triassic and Permian	O Ordovician		X Lower and Middle Proterozoic	\equiv	of unknown age Areas outside of the former Soviet Union	\wedge	Geologic contact
K. Cretaceous (undivided)	PC Permian-Carboniferous	OCm Ordovician-€ambrian		A Archem	333	Arctic areas covered by Ice	Just.	International boundary
KJ Cretaceous and Jurassic	C Carboniferous	Cm Cambrian	*****	Qv Extrusive rocks Pliocene and Quaternary	Page (10.1)	Sea and large lakes	*	Major cities

STUDY AREA AND DATA SOURCES: ENERGYBASE.RU

Energybase.ru provides the location (city) of 558 currently operating oil and gas wells in Russia



STUDY AREA AND DATA SOURCES: ENERGYBASE.RU

- Oil/gas production data available for 98 wells
- **Example:**



Ванкорское месторождение АО "Ванкорнефть"

<u>но рапкорпофию</u>

Город **Игарка** Фазовое состояние **нефтегазовое** Извлекаемые запасы A+B1+B2+C1

479.10 млн. тонн



<u>Русское месторождение</u> ПАО "НК "РОСНЕФТЬ"

Город

Тазовский

Фазовое состояние

газонефтяное

Извлекаемые запасы А+В1+В2+С1

422.00 млн. тонн



<u>Лянторское месторождение</u> ОАО "Сургутнефтегаз"

Город

Фазовое состояние

Извлекаемые запасы A+B1+B2+C1

Лянтор

нефтегазоконденсатное

380.00 млн. тонн

WEB SCRAPING ENERGYBASE.RU

```
wellsdat <- NULL
for (pg in 1:28){
 webpage <- paste0("https://energybase.ru/oil-gas-field/index?page=", pg) %>%
  read html(encoding = "utf-8")
 out <- webpage %>%
  html_nodes("div.name, div.info") %>%
  html_nodes("a, small a, small, div.value") %>%
  html_text()
 out <- out[grepl("\n", out) == FALSE]
 wells <- as.data.frame.vector(out)</pre>
 wellsdat <- rbind(wellsdat, wells)</pre>
write.csv(wellsdat, "wellsdat.csv", row.names = FALSE)
```

WEB SCRAPING ENERGYBASE.RU

```
sites <- NULL
for (pg in 1:28){
    webpage <- paste0("https://energybase.ru/oil-gas-field/index?page=", pg) %>%
    read_html(encoding = "utf-8")
    out <- webpage %>%
        html_nodes("div.name > a") %>%
        html_attr("href")
    site <- as.data.frame.vector(out)
    sites <- rbind(sites, site)
}
write.csv(sites, "sites.csv", row.names = TRUE)</pre>
```

WEB SCRAPING ENERGYBASE.RU

```
<div class="item">
    <small>
        Координаты:
    </small>
    <br>
    <a href="#yandex-map">Широта: 45.000278</a><br><a href="#yandex-map">Долгота: 48.561944</a>
                                                                                                                </div>
                                                               colnames(coords) <- c("lat", "long")
sites <- read.csv("sites.csv")
                                                               coords$id <- as.numeric(row.names(coords))</pre>
coords <- NULL
                                                               coords$lat <- str_extract(coords$lat, "[[:digit:]].*$")</pre>
for (i in 1:nrow(sites)){
                                                               coords$lat <- as.numeric(coords$lat)
 site <- sites$out[i]
                                                               coords$long <- str_extract(coords$long, "[[:digit:]].*$")
 webpage <- paste0("https://energybase.ru", site) %>%
                                                               coords$long <- as.numeric(coords$long)
  read html(encoding = "utf-8")
                                                               write.csv(coords, "coords.csv", row.names = FALSE)
 out <- webpage %>%
  html_nodes("section.contacts div.item > a") %>%
  html_text()
 coord <- as.data.frame(cbind(out[1], out[2]))
 coords <- rbind(coords, coord)
```

TRANSLATING WELL TYPES IN ENERGYBASE.RU

```
types_ru <- unique(wells_all$type)
types_ru <- paste0("^", types_ru, "$")
types_en <- c("oil-gas", "gas-oil", "oil-gas-condensate", "oil",
    "gas-condensate", "gas")
wells_all$type_ru <- wells_all$type
for (i in 1:length(types_ru)){
    wells_all$type <- gsub(types_ru[i], types_en[i], wells_all$type)
}</pre>
```

Туре	Known Production	Unknown Production
Gas	0	49
Gas- condensate	4	77
Gas-oil	3	4
Oil	54	195
Oil-gas	12	48
Oil-gas- condensate	22	82

METHODOLOGY: INVERSE-DISTANCE WEIGHTING

Inverse-distance weighting of petroleum yield using

$$p_i = \sum_{j=1}^n \frac{1}{d_{ij}^2} p_j / \sum_{j=1}^n \frac{1}{d_{ij}^2},$$

where p_i is predicted petroleum yield for well i, p_j is known petroleum yield for well j, and d_{ij} measures the distance between two wells i and j

METHODOLOGY: INVERSE-DISTANCE MATRIX

1

 $A_{249,249} \cdot A_{249,249}$



 $D_{249,249}$

Distance Matrix (Great-circle distance, in kilometers) Inverse Distance Matrix (symmetrical)

```
writeDist(rdist.earth(oil.mtrx, miles = FALSE, R = 6366.71), file = "oil.mtrx.csv")
oil.mtrx <- read.delim("oil.mtrx.csv", header = FALSE, sep = " ")
oil.mtrx <- as.matrix(oil.mtrx[2:250,2:250])
for(i in 1:dim(oil.mtrx)[1]) {oil.mtrx[i,i] = 0}
mtrx.dist.inv <- ifelse(oil.mtrx!=0, 1/(oil.mtrx*oil.mtrx), oil.mtrx)
dist.inv <- as.data.frame(mtrx.dist.inv)
dist.weights.sum <- as.data.frame(rowSums(dist.inv))</pre>
```

METHODOLOGY: GEOLOGICAL PROVINCE MATCH

GLG Vector (Character)

Geological Match Matrix (binary and symmetrical)



 $G_{249,249}$

```
mtrx.glg <- matrix(NA, nrow = 249, ncol = 249)
for (i in 1:nrow(oil.wells)){
  for (j in 1:nrow(oil.wells)){
    mtrx.glg[i,j] <- ifelse(
      oil.wells$GLG[i] == oil.wells$GLG[j], ifelse(
      i!= j, 1, 0),
      0)
  }
}
glg <- as.data.frame(mtrx.glg)
glg.weights.sum <- as.data.frame(rowSums(glg))</pre>
```

METHODOLOGY: PRODUCTION WEIGHTS

Production Vector (numeric)

Production Weights Vector (binary)

$$O_{249,1}$$
 $V_{249,1}$

Min: 1.80

Mean: 63.87 prod <- as.matrix(oil.wells\$prod)

Max: 360.0 prod[is.na(prod)] <- 0

Not Missing: 54 prod.weights <- prod

Missing: 195 prod.weights[is.na(prod.weights)] <- 0

N: 249 prod.weights[prod.weights > 0] <- 1

METHODOLOGY: WEIGHTS CALCULATION

Inverse Distance Matrix

Geological Match Matrix

Production
Weights Vector

Weights vector

$$D_{249,249}G_{249,249}V_{249,1} = W_{249,1}$$

dist.glg.weights.all <- mtrx.dist.inv %*% mtrx.glg %*% prod.weights

METHODOLOGY: WEIGHTED PREDICTIONS

Inverse Distance Matrix

Geological Match Matrix

Production Vector

Weights vector

Predicted production vector

$$P_{249,1} = \frac{D_{249,249}G_{249,249}O_{249,1}}{W_{249,1}}$$

dist.glg.weighted.pred <- mtrx.dist.inv %*% mtrx.glg %*% prod dist.glg.pred <- dist.glg.weighted.pred/dist.glg.weights.all

METHODOLOGY: EVALUATING THE PREDICTIONS

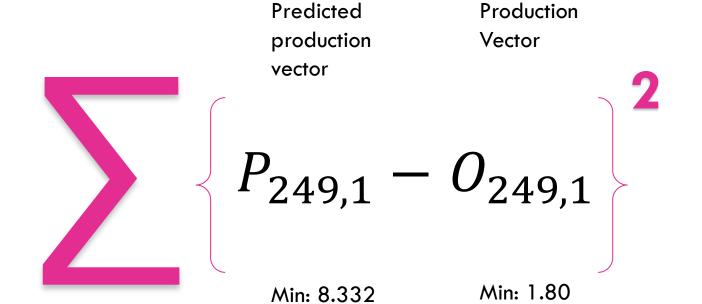
Mean: 63.87

Max: 360.0

Missing: 195

N: 249

Not Missing: 54



Mean: 57.014

Max: 108.477

Not Missing: 54

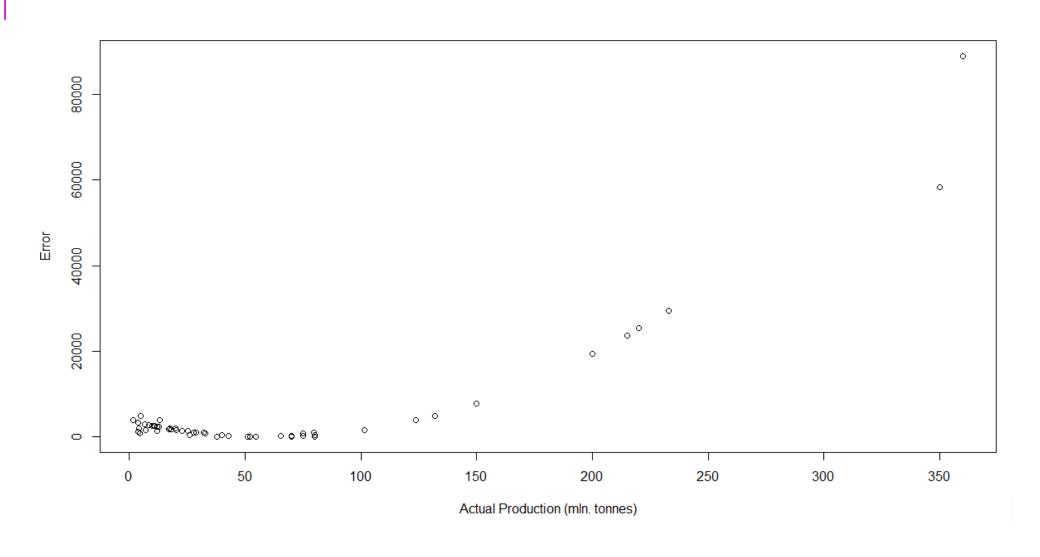
Missing: 195

N: 249

Sum of squared errors
Inverse-distance weighted: 513,153.1
Geological match weighted: 517,393.6
Weighted by both:

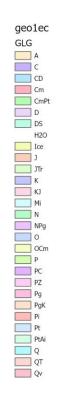
327,098.6

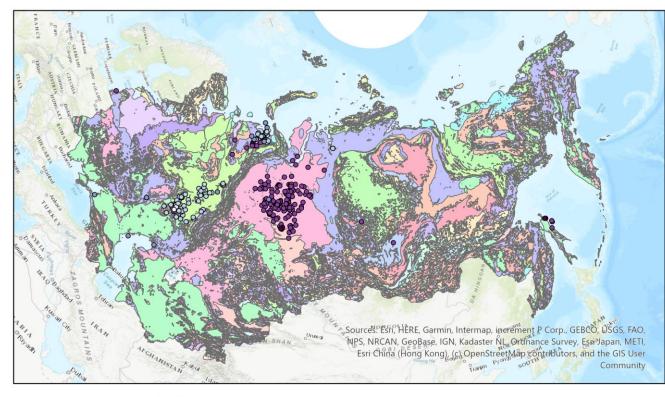
METHODOLOGY: EVALUATING THE PREDICTIONS



PREDICTED OIL PRODUCTION

Map of the Geological Provinces of the Former Soviet Union





437.5

875

1,750 Miles

A

Oil Wells

Predicted Oil Production (Million Tonnes)

- O ≤38.695307
- **O** ≤51.730824
- ≤58.513942
- <70.325022
- ≤108.476821

SOURCES

Aguilera, R. F. (2011). Modeling petroleum resources in provinces of the Former Soviet Union. Energy Exploration and Exploitation, 29(4), 379-396.

Campbell, Robert. (1968). Economic Reform in the USSR. The American Economic Review, 58(2), 547-558. Papers and Proceedings of the Eightieth Annual Meeting of the American Economic Association.

Charpentier, R. R., and Klett, T. R. (2005). Guiding principles of USGS methodology for assessment of undiscovered conventional oil and gas resources. Natural Resources Research, 14(3), 175-186.

Hamida, et al. (2017). An efficient geometry-based optimization approach for well placement in oil fields. Journal of Petroleum Science and Engineering, 149, 383-392.

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