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With regards from,

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PROPERTY RECORDS AND METHODS OF DETERMINATION OF PROPERTY BORDERS – FROM THE EARLIEST TIMES TO THE MIDDLE AGES IN EUROPE

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Abstract. In the article the question of the formation of customary law norms was presented, which was determined over the centuries, from ancient times up to the Middle Ages in Europe. These norms were establishing rules for the determination of land boundaries, the mode of ownership transfer function, and identified persons who are entitled to certain rights to separated area of ground. They also led to the creation of the first mortgage registers, which are prototype of today's real estate cadastres and real-state registers.

From the very beginning of establishing the institution of law, the official records of the property created, were ensured certainty in legal trading and public needs, associated in particular with the land tax collecting. The creation of real-state registers institutions resulted in a situation where certain part of ground, properly marked and disclosed in the mortgage registers, took on the characteristics typical for material things, by what it has become a commodity that could be the subject of sale or provision of cash receivables, which consequently led to the development of mortgage institution in antique law, which was taken over, with some modifications, to the Roman law and then to the codification of other medieval European states.

Key words: cadastre, cadastre history, property registers, real estate registers, property borders, land registers, mortgage records, ways of transferring the right of ownership

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THE FIRST MENTIONS OF METHODS OF DETERMINATION OF PROPERTY BORDERS AND RECORDING RIGHTS TO GROUND REAL ESTATE

The earliest, from the known, forms of registration of subjective rights to land ownership were discovered in the valley of the Euphrates and Tigris, and are dated back to about 6500 BC. In area of city of Nuzi, existing at the Babylonian times, 200 tables from baked clay were found, on which the data was read with the description, dimensions, and the purchase price of plots of land, which were the evidence of entitlement to own things and use its benefits[1]. The right to land was protected in that region in such a way that the points defining the range limits (boundaries) of that law have been properly prepared stabilized boundary stones (*stela's*). The evidenced for that was found in the Telloh village inhabited by Semitic peoples (in the valley of the Euphrates), where the boundary stone and clay tables (dating about 4000 BC) were located, on which in cuneiform information was inscribed with the description of the land, including their surfaces, dimensions, and the identity of the holder and spells designed to protect both the boundaries of ownership, as well as their owner[2].

The obligation to save the acts of ownership transfer on clay tablets and their storage was set directly in the Code of Hammurabi[3]. Public breaking the table with the sale contract was equivalent to the cancellation of the entire transaction (§37 of the Code). Separated properties, owned by an individual, were marked on the ground by stone boulders of up to 1 meter high, called *kadurru*, which were proof of granting land by the sovereign. On these stones inscriptions were carved containing information about the act of granting and the transition of ownership to a specific person, as well as various types of spells, which should protect the holder against interference of third parties[4]. Each boundary stone *kadurru* had his copy, which was kept in the temple as an independent proof of acquired rights in the event of their questioning. *Kadurru* stones played two roles. In one hand they were a document confirming the range of rights on the ground, in other hand they played a role of a document that deposited in the temple (public register) which was a guarantee of protection of property, and became a symbol for the derivative acquisition of individual property rights[5].

By the Assyrian law, the transfer of the rights to land to the purchaser required the preservation of form of the public preparation of sale contract (duppa dannatu) against the royal authority. In some regions of the ancient Assyria (eg Kirkuk-Nuzi) it was neces-

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[1]   J. Wolski, Cadaster of ground tax on Polish lands, „Przegląd Geograficzny" 2001, Nr 73, pos. 1–2, page 107108.

[2]   *Ibidem.*

[3]   The Code of Hammurabi is one of the oldest codes of the world. It was prepared by King Hammurabi (1728–1686 BC), the sixth representative of the Babylonian dynasty. It was found in She by French scientific expedition in Susa.
      The text of the Code was engraved on a 2 meters height block of diorite in cuneiform – quote of K. Krasowski, B. Lesiński, K. Sikorska-Dzięgielewska, J. Walachowicz, *Common History of State and Law*, Poznań 1993, page 274.

[4]   R. Taubenschlag, *Roman private law on the background of ancient laws*, Warsaw 1955, page 114.

[5]   K. Koranyi, *General History of State and Law*, Warsaw 1961, vol. I, page 16; quote of T. Stawecki, *The records of real estate, mortgage books and land registers from the earliest times to the twenty-first century*, Studia Iuridica XL/2002, page 168–169.

sary to measure plots of land sold with the use of the official measure, made by a person "widely respected" called mušelmŭ. Those actions were necessary for effective transfer of relative ownership, between the contract parties. Mušelmŭ functioned as public identifier of the contract subject and provided the basis to produce a further document recording the contract, which was subjected to public announcement so the contract has effect against third parties[6]. Prepared sales documents and their copies were stored in the courts (registered) or the temples performing such a function. Weaknesses in the form and mode of sale and registration, may be a reason to make accusations of stealing things, which could result in the death penalty[7].

In ancient Athens, property boundaries[8] were marked with stone boulders called *horoi* (*horos*)[9]. There were some information placed on those stones. First of all, it identified the holder of the property, but also contained information of extended loans that were secured on the property (mortgage poles). Inscriptions placed on boundary stones provided, among others, the fact that so designated plot of land was burdened to repurchase in the event of its sale. Stone columns, by the Greek called Ὄρος,Ὄροι were used to ensure security in legal transactions, informing all concerned parties that the marked property is a security for property claims arising from a particular contractual relationship, which is confirmed by the quote of Pollux IX 29: "*Horos* is the public registry placed on the estates and land, raised for those who take them in the pledge, because of what the owners are indebted, on the *horos* is written, that this land or property is occupied because of the debt, so no one make a contract with those, whose lands are occupied"[10]. Detailed inscriptions were placed on pledging columns informing whether the pledge applies to the land or for the entire assets of the debtor, the creditor's name was disclosed and the information was given about the name *archonata* (the most important official of *polis*) at the time, in which the debt provision was made, sometimes the inscriptions were also disclosing the sum of money of secured monetary obligations established in the form of *hypotheca*[11].

A rule has been adopted that in the case where the height of a financial liability (pledge) exceeds the value of land, the creditor was entitled to keep its owner as a mercenary or permission to sell it to recover the missing amount[12], which led to a massive "repurchase" of pledged property by the landowners.

Pledging columns were removed scarcely by Solon, who introduced reforms in which he annulled the obligations laid down against the *polis* (years 594–593 BC), which was called "getting rid of weights (*sesjachteja*), buying at the expense of state the owners of pledged lands" thus abolishing the institution of "debt slavery". The land and real estate taken was returned to former owners, and the restrictions have been established fixing the maximum amount of land that can be owned by one person.

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[6] R. Taubenschlag, *op. cit.*, page 116.

[7] *Ibidem.*

[8] Greek law didn't definitively distinguish the division of ownership and possession (*katechejn*).

[9] Por. T. Stawecki, *Public registers. Functions of the institution*, Warsaw 2005, page 183.

[10] Quote of J. Rominkiewicz, *Care over male pupils in the Athenian law*, Wrocław 2003, page 117.

[11] At the columns *horoi* the amount of debt was not disclosed that has been established in the form of *apotimema* – this form of debt provision (other than *hypotheca*) was used for leased property and securing a dowry – quote of J. Rominkiewicz, *op. cit.*, page 117 and further.

[12] T. Maciejowski, *Common history of the constitution and the law*, Warsaw 2007, page 12.

By Plato the information about land parcels that were assigned to the settlers, was written down on tablets of cypress wood, which were kept in the temple "for later use"[13].

Disposal of rights to property required a necessary notification of intention for sixty days from the date of the proposed transaction, before the clerk which was to serve the rights of potential purchasers or creditors[14]. The formal requirement for an announcement about the sale of real estate has been implemented in some Greek city-states, by posting messages in a public place about the proposed transaction or in the form of notice given to the public by the herald a few days before the planned sale and writing entry in the official registers[15]. However the rights to land were not registered, nor protected in the same way in every Greek city-states. In some, such as Sparta the rule was forced that every citizen is entitled to one and the same size plot of land allocated to him by lottery, which meant that the actual "trading" was really performed on the basis of inheritance and family law[16]. So given plot of land could not be used as protection for the claims or was not subject to transfer of rights to another person (alienated).

In Egypt, in first age of our times was functioning the first, in the modern sense of the word, real estate register called archive of possession acts (*bibliotheke enktesenon*), which primary role was to collect evidence of ownership rights to real estate property and tangible protection of granted claims (mortgage charge). In the conducted records there was written other important information about the property and its owner, as well as indirectly linked to it, and for example the amount of slaves performing specific work concerning the described thing, and all this in order so "any person acquiring rights not may have been deceived by his ignorance"[17].

Implemented system of registry books was to ensure certainty and security of legal transactions, and was also used for fiscal purposes allowing the sovereign to clearly determine the person liable to pay applicable taxes and their size.

It is worth noting, that these operations were performed through a special network of offices located in the capitals of districts that were required to keep books called *diastromata*, in which all data to be recorded was subject to disclosure. When analyzing the system that was existing at that time for recording rights to land, it should be noted, that entry into the book (*diastromata*) was made under a specific procedure[18] called *katagraphe*. During this procedure the act was drawn up transferring the rights to the land (now called the authenticated deed), which then – at the request of official who made it (notary) – was forwarded to the office managing the books, which issued a decree (*epístalma*) confirming the validity of the transaction. Issued decree was the only basis to disclose the acquired rights in the book (constitutive entry).

In the Hellenistic period during the time of the Alexandria law, the seller was obliged to make a formal act for the effectiveness of the alienation operation. The act involved the public release of the sold goods to buyer, during which he invited the neighbors who filed a declaration confirming that he is entitled to sell the property which is the subject of the contract. For participation in these activities, neighbors – witnesses, received adequate

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[13] Quote of Plato, *Laws*, Warsaw 1960, page 200.
[14] Quote of T. Stawecki, *Real estate registers* ..., page 169.
[15] Quote of K. Koranyi, *General history* ..., page 83.
[16] *Ibidem*, page 206.
[17] Quote of T. Stawecki, *Real estate registers...,* page 171.
[18] Today known as the institution of entry to the register.

remuneration in the form of border fee. Sides of the contract were required to pay the tax and to submit a report of the conducted activities to the city treasurer, who then prepared on this basis a public document which was basis for entry in the cadastre of real estate. Only when the sales act was disclosed in the carried registers it was considered that the property is absolutely entitled to its purchaser[19].

The role and importance of conducted at that time registers, and Egyptian surveyors, can provide a quote of Herodotus: "if it turned out that the water took the part of the subject field, then the king sent his officials to confront the field size and properly reduce taxes"[20]. Quoted records may constitute proof of what importance was attached to the timeliness of data related to the register of land and fact that they served important public and legal functions.

Registration of rights transfer, gathering evidence of conducted activities and stabilization of property boundaries, were aimed by ensuring not only the reliability and security of legal transactions, but also the possibility of clear determination of the persons liable for the provision of public tribute to the ruler (for tax purposes).

How important was this problem in the past, may be indicated by the part of instructions issued about 1400 years BC by Department of the Measurements in the current State of the Pharaohs, which stated: "Do not remove the boundary stones on fields and do not change the positions do of the measure tapes" (Amenhotope, son of Kanakhta, Teaching, Chapter VI)[21]. In the quoted manual a mode and procedure was described for the settlement of border disputes, on the basis of the prepared documentation, which is confirmed by the contained record: "When the applicant comes in and announces: Our border signs have been removed – he must obtain access to information stored and sealed by the appropriate officer and, consequently, recover what was taken from him by the assembly, which removed the border signs"[22].

The development of metrology in ancient Egypt resulted from the need to ensure the ability to clearly reproduce the position of the boundary signs designating the range of separated parcels of land that were taxable and destroyed by the annual flooding of the Nile. It had to be a system that would guarantee every land owner a sense of certainty about the possibility of proper marking the object of his rights to the land. When the water fell, destroying the border signs (hedges, stone, etc.), there were often disputes which were settled by inspectors authorized to recreate borders on the ground, place boundary stones and their measurement.

Scenes presenting the work of the so-called inspectors with the use of "rope tensioners" can be found on the walls of tombs, where buried ancient Egyptian measurers were presented (ca. 1400 BC). They were also called the rope tensioner and were senior members of the cadastral office. What more, they were entitled to wear white linen wigs as a sign of their dignity, and were well-paid civil servants of Pharaoh. It is confirmed by

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[19] R. Taubenschlang, *op. cit.*, page 117.
[20] Quote of Herodotus, *History*, Warsaw 1954, page 164.
[21] Quote of Johan F. Brock, *Who Were the First Surveyors, Four Surveyors of the Gods: In the XVIII Dynasty of Egypt – New Kingdom c. 1400 B.C.*, International Federation of Surveyors. Article of the Month, March 2005.
[22] *Ibidem*.

the impressive tombs – the walls which presented scenes from their lives, including the techniques used in the measurements[23].

In Rome, as in the other parts of the world, land property was determined by setting the boundary stones, and the content of act of ownership transfer was written down in public, on wooden tablets (*tabula cerata*)[24], in front of a representative of public authority (praetor or governor). In the process mode, and in result there was a departure of law; or as a result of private actions, but requiring the presence of witnesses, and the person responsible for the accurate determination of payment called *librepens* ("holding weight")[25]. Certain formal and ceremonial activities associated with the transfer of rights to property were used to reinforce the impression in the minds of people presented about the importance of performed activity and at the same time ensure their perpetual existence[26].

How important was this problem for contemporary Romans, is evidenced by the fact that for the protection of property boundaries between private estates, they established a god called Terminus. His statue was located in the temple of Jupiter on the Capitol, and there was also festival called "Terminali" celebrated in his honor on February 23[27]. On that day the boundary stones were decorated with flowers, and people practiced sacrifices around them.

The issue of marking boundaries of land ownership also found its place in written form in years 451–450 BC. The Act of XII Tables (*lex tabularum*), occupied unique and special place in Roman law[28]. In the 69th fraction of the 8th table of the Law was written: "so the boundaries of land ownership were not doubtful, five feet of free space between the land, just like in the law of Solon, the owners should leave, and expiration does not hurt this regulation". Another regulation (fraction 70th, Table 8th) said that "in cases concerning the boundaries between neighbors, praetor will appoint three arbitrators"[29] who should adjudicate the dispute.

In Roman law, the boundary separating adjacent agricultural lands was treated as a kind of land co-ownership, which could be demarcated (divided) only with a consistent request of all interested landowners. In the case of *agri limitati*, around each plot strip of land (*limes*) was marked out by surveyors with a width of 5 feet, which was excluded from the crop and as such was not subject to acquisitive prescription (*usucapioni*). It was

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[23] Quote of K. Sawicki, *Five centuries of Polish geodesy*, Warsaw 1964, page 8–9; I. Salmon, *Geodesy in Ancient Egypt*,

[24] *Ibidem*, page 172.

[25] Quote of K. Kolańczyk, *Roman Law*, Warsaw 1997, page 299–300.

[26] Gaius Institutiones – volume I, part 18, page 119–122. "Mancipatio is, and it was said above, some kind of pretended sale, it is also right actual for Roman citizens, and and it is done in the presence of no less than five adult Roman citizens, and besides, even one more in the same state, who holds bronze weight and is called libripensem, the one who receives the thing in mancipium when holding and so says: Ego hominem ex iure quiritium meum esse aia isque mihi emptus esto hoc aere aeneaque libra, then hits the weight with the bronze and gives it to person from whom he takes in mancipium, in the place of money". Access: http://www.karnykodeks.pl/prawo/gaius-institutiones-ksiega-i-cz18.html.

[27] Quote of T. Czacki, *About the Lithuanian and Polish laws, the spirit, sources, and therefore the things contained in the first statute of Lithuania issued in 1529*, Warsaw 1801, vol. 2, page 176.

[28] Quote of K. Kolańczyk, *op. cit.,* page 37–39.

[29] Quote of A. Korwicki, *The boundary process*, Vilnius 1827, page IX.

to be used for communication purposes and to provide owners of adjacent properties possibility of cultivation of the land "by converting the plow"[30].

The boundary line (*finis*) ran in the middle of specified *limes* (balk), dividing it into strips with a width of 2 ½ feet, which – as an integral part of the adjacent properties – were affected by the law (servitude) to allow a common use for specific purposes related to the handling of these plots of land.

In the case of breaching the border of the parcel each owner or owners of the land adjacent to the parcel could bring a complaint to the court for rectification of the border, called *acito finium regundorum*, which was a personal nature complaint (*acito in personam*) and was different from the mining complaint, due the fact that in its course disputes about ownership ratios (petitory claim**)** were not decided in relation of the disputed strip of land or rights to its ownership (possessive claim).

In classical Roman law[31], the act of transferring the right to goods from one entity to another known to be derivative acquisition of ownership, was controlled by two fundamental legal principles – the first which stated that "nobody can transfer to another person more rights than those granted to himself (*nemo plus iuris ad alium transferre potest quam ipse habet*). The act was called an assignment (*alienatio*) or legal consequence (*successio*). According to the second legal principle, the right of ownership is transferred by giving or acquisitive prescription, and not by a bare agreement (*traditipnibus et usucapionibus dominia rerum, non nudis pactis transferuntur*)[32]. The first of these principles set down the limits of effective acquisition of property rights only from an authorized seller (owner) in the range of the vested rights (translative or constitutive acquisition)[33] stating that the acquisition of rights (even in good faith) from unauthorized seller was absolutely ruled out and could result in filing a complaint for debt collection and the need to return the purchased property. Action of purchasing ownership of goods from unauthorized source could be sanctioned only by the institution of acquisitive prescription. In this case short (one or two years) terms applied, after which there could be "a healing of failed assignment"[34]. The second criterion was that for the effectiveness of an alienation it was necessary, to make a formal executory act involving the release of goods sold to the purchaser. It was in addition to writing the contract that was exerting binding effects (*iusta causa*),

At the time of Gaius (II century AD), the only way to transfer ownership was method called *moncipatio* (act with witnesses) which was widely practiced. The method in its initial form (III century BC), was confined to the direct act of exchange of divested things

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[30] Quote of S. Wróblewski, *An outline of the lecture of Roman law,* Kraków 1919, page 84.

[31] We are assuming the division of law into three periods: the archaic period starting with the beginning of the existence of Rome, until the Punic Wars (264–146 BC), ie the end of the republic; the period of classical law dated from mid-third century BC ie the beginnings principate up to 235 BC ie Sewer Dynasty; and a post-classical period (called vulgar law), measured from the end of the Sewer reign, until the death of Justinian I (235–565 AD) in which still stands out the subperiod of Justinian law (527–565 AD) – quote of K. Kolańczyk, *op. cit.*, page 13.

[32] W. Dajczak, T. Giaro, F. Longchamps de Bérier, *Roman law at the basis of private law*, Warsaw 2009, page 378.

[33] Translative acquisition meant that the buyer could move as many rights as possessed, and the constitutive include situations in which there was only a partial transfer of ownership rights held by the vendor.

[34] W. Dajczak, T. Giaro, F. Longchamps de Bérier, *op. cit*., page 378.

for the payment in the amount of measured weight (weighing payment)[35] in the form of ore (usually copper). The original form of this method survived to the times of money circulation (III century BC), which as a payment unit subjected to counting, ousted the need for "weighting" payment. Since then, finding the transition of ownership right to the thing has a symbolic, yet formal (causing legal effect) character and was restricted to public transfer of monetary unit (*nummus unus*) between stakeholders, or any piece of gold (*raudusculum*) in the presence of at least five witnesses, who has to be Roman citizens, and person holding a weight (*libripens*). Act of transferring the ownership right was limited to enunciating the formula by purchaser, in which he described acquired right to things, and the symbolic hitting weight by coin (substitute of weighing payment), which was then handed to the seller as a symbol of proper payment[36].

Moncipatio method, considered as a formal act of ownership transfer in the presence of witnesses, had been used particularly in the selling of so-called quiritary ownership (*dominium ex iure Quiritium, proprietas*). It was official and protected form of property in the Roman civil law in both-classical and pre-classical period, and was entitled only to the citizens of Rome called Quiritians and included movable and immovable properties situated in Italy. The act of ownership transfer *moncipatio*, preceded by a sale contract and payment is therefore in today's meaning an abstract, detached in its symbolic, both from the legal cause, for example the content of the agreement and the fiscal element[37].

This method was widely used until the introduction of so-called "bonitary ownership" recognized by magisterial law (*possessio ad interdicta*), and shaped under the influence of practice that over time eliminated burdensome formal acts (civil law). It was associated with the transfer of quiritary ownership, replacing them with simple solutions of releasing goods by the seller into the hands of the buyer (*traditio*) that should accelerate the realization of transactions. As a result, the buyer became the owner of a thing (*possesion civilis*) that only over time[38], could become its quiritary property within the meaning of civil law as a result of acquisitive prescription (*usucapio*). During the transitional period leading to the prescription, the holder (informal buyer) rights were protected by possession interdicts[39] through legal pleas, and special petitory complaint (*actio publiciana*)[40], which was entitled to the holder of the thing in good faith.

During postclassical period the transfer of ownership to thing was done in the framework of actions called *in iure cessio* (from Latin *cedere* – yield, depart) defined in Roman

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[35] Quote of K. Kolańczyk, *op. cit*., page 298; quote of W. Dajczak, T. Giaro, F. Longchamps de Bérier, *op. cit*., page 379–380.

[36] K. Kolańczyk, *op. cit.,* page 299.

[37] *Ibidem*, page 286–287

[38] Typically, this was a period of two years.

[39] Possesory interdicts protected the right of ownership, which was recognized by praetorian law. It was a out of process form of protection which, defined by the praetor, established the rules settling rights of the sides to the disputed ownership of things. There were three types of Possesory interdicts: *retinendae possessionis* (maintenance of existing ownership), *recuperandae possessionis* (recover lost possession) and "*adipiscendae possesionis*" (to buy the new ownership) – quote of K. Kolańczyk, *op. cit.*, page 287–288.

[40] Actio Publiciana – complaint, which entitled the holder of the thing in good faith in the period leading to the prescription, to its release or termination of infringements, which established the adoption of a legal fiction which consists of equating the rights of the holder and owner in the range of protection of things petitory protection.

law as a method of waiving right before the court and the derivative acquisition of quiritary ownership. These activities had the nature of the apparent debt collection process conducted between the sides of the agreement, under which in the first phase the buyer of a right, placed as an apparent reason, declared before the Praetor[41], while making a symbolic touch of purchased item with the staff, indicating that the thing he pointed belongs to him[42]. Subsequently, the seller of things (the apparent defendant) recognized the reported complaint or remained silent, which meant acceptance of the claim, and thus meant that he lost the debt collection process (apparent), which ended in an act of granting by the praetor "disputed" thing to the plaintiff (buyer)[43]. Due to the nature of the legis actio procedure (*per legis action es*)[44], participants in this formalized, but still abstract legal action *in iure cessio* could be only Roman citizens holding a judicial capacity. So formed claim could not be fortified by the condition (*conditio*), or the date (*dies*) of its investigation[45]. As a method of derivative transfer of ownership, it went into disuse in the sixth century and was formally abolished in the Justinian codification[46].

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[41] Praetor is a senior official in ancient Rome with the so-called. lesser power (*imperium minus*) primarily engaged in the civil judiciary – quote of. *Small encyclopedia*, red. B. Petrozolin--Skowrońska, Warsaw 1995, page 707.

[42] *Gaius Institutiones* (G. 4.16): "If people processed about things, things both moving and alive, which could be brought or taken to the official, they were vindicated in front of officer: he who vindicated, held the pole, then captured the thing, for example a slave, and so he said: "*Hunc ego hominem ex iure quiritium meum esse aio secundum suam causam, sicut dixi, ecce tibi vindicatam imposui*"(I declare that this is my slave, according to the law of Quirites, as I said, here I put the staff on you) and at this time touch the slave with the staff. His opponent said and did the same. Since both have conducted vindication, praetor said: "*mittete ambo hominem*" (let go of the slave), and they released him. He who first vindicated, asked the second one: "*postulo anne dicas qua ex causa vidicaveris*" ("I demand that you said, for what reason you have vindicated"). He answered "*ius feci sicut vindictam imposui*" (I executed a law, like I put the staff). In the end, the one who vindicated first said "*quando tu iniuria vindicavisti quingentis assibus sacramento te provoco*" (And what if you vindicated with the insult of laws, I urge you to set a sacramentum of five hundred aces). The enemy also spoke similarly "*et ego te*" (and so do I). Staff was used in place of the spear, the obvious sign of the legal power, because they thought that legal power arose from these things that they seized from the enemies"; access: http://www.karnykodeks.pl/prawo/gaius-institutiones-ksiega-i-cz16.html.

[43] *Gaius Institutiones* (G.2.24): "The withdrawal is made before the law in this way: to an official of the Roman people, for example, the urban praetor, the one to whom the thing is departed before the law, holding thing, says, "*Hunc ego hominem ex iure quiritium meum esse aio*" (I declare that this is my slave, according to the law of Quirites). Then, when it was vindicated, praetor asks the one who departs, whether he will perform contrvindication. When he is silent, or denies, in this way he admits the thing to the one who vindicated"; access: http://www.karnykodeks.pl/prawo/gaius-institutiones-ksiega-i-cz2.html.

[44] Legisaction proceeding (*per legis actiones*) – is the oldest form of judical procedure in the Roman law – quote of W. Wołodkiewicz, M. Zabłocka, *Roman law. Institutions.*, Warsaw 2009.

[45] Por. K. Kolańczyk, *op. cit.*, page 299–300.

[46] The Code of Justinian (*Codex Iustinianus*) is one of the three parts of a great compilation of Roman law undertaken in the years 528–534 by Emperor Justinian I the Great, known under the medieval name of Corpus Civilis Iuris – quote of K. Kolańczyk, *op. cit.*, page 37–38.

Legal institution, which for years has established rules of transferring rights to the property, was defined in the classical period[47] of development of the Roman Empire as a method called *traditio*[48]. The method determined the conditions for the effectiveness of legal action, and has survived in various forms until the nineteenth century civil codes [49]. The solution adopted at that time, makes the effectiveness of the ownership transfer function conditional on the release of the transaction assets (things) by its current holder, in accordance with the established principle of "*Traditionibus et usucapionibus dominia rerum non nu dis pactis transferentur*". It meant that the ownership of thing is transferred through "giving and prescription" and not only through the contract[50]. Effective transfer of ownership to the buyer required the separate step of a symbolic nature such as public (visible to the environment) transfer of the right to the subject of the contract by interested parties apart from writing down the contract (*nudum pac tum*). The effectiveness of these activities was assessed in the context of the established general principle "*nemo plus iris alium transferre potest, Guam ipse habet*" (no one can move to another person more rights than he has), which was to protect the rights of the owner against unauthorized disposal[51].

Defined in the classical and Justinian law, the procedure of transferring the right of ownership consisted of two phases. The first of which concerned the activities of a required character ("naked agreement" – a contract for the sale of things), and the second – statutory action consisting in an open and formal release of the contract subject. *Traditio*, as a method of transferring the right of ownership to things (*modus*), thus did not require the presence of persons other than the interested parties, that is the seller having ownership title, able to dispose of its laws, and the buyer, who expressed their willingness to transfer the right. However as a causal act it was confined to the releasing to the buyer physical possession or ownership (*possessio*)[52] of thing that condition the consequences of the existence and of acceptability of legal cause, that is the concluded contract of sale requiring to deliver things to the purchaser[53].

Established rule, that was a condition for validity of the right to the thing transfer from the point of physical delivery, was a subject in later period[54] to numerous modifications. The changes aimed essentially to replace this action with a requirement to register the contract that was basis for the transfer of right, handing a written statement of the seller (*traditio instrumentali*) or a necessity of public disclosure of acquired rights, which could constitute a sort of element of social control and tangible evidence that this right is granted to a person revealed in this way.

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[47] Dating from the early principate (27 BC) to takeover of power by Diocletian (284 AD), quote of K. Kolańczyk, *op. cit.*, page 34–35.

[48] *Tradere* means: release, give.

[49] For example, the Austrian Civil Code (ABG) from 1811.

[50] *Gaius Institutiones* – D.41.1.31pr (Paulus, book 31 commentarz to the Edict): The mere release of thing does not transfer ownership, but only if it was preceded with the sale or some other good reason of handing thing over;
access: http://www.karnykodeks.pl/prawo/gaius-institutiones-ksiega-i-cz16.html.

[51] Quote of K. Kolańczyk, *op. cit.*, page 297.

[52] During the vulgarization of Roman law (IV–V century), the term was used both to determine ownership and property rights.

[53] Por. K. Kolańczyk, *op. cit.,* page 300–302.

[54] At the time of the Justinian law.

Another variety of modification to the *traditio* rule was to replace the physical condition of releasing the ownership of goods with the act of granting to the buyer official documents confirming the validity of the act of transferring the right of ownership, and also allowing determination of the subjective range of the right, ie the boundaries of the acquired property. In medieval England or Germany, it was required to release it in public places for the effectiveness of transferring the right to thing to third parties, for example on the market, in the church or court[55]. The need for a practical simplification of the rules in legal transactions was therefore cause for modification of the original *traditio* method, aimed at dematerialisation of this activity in the range of *corpus* (things), and replacing it by a symbolic act, which make the process of ownership alienation of property act of abstraction. It should be stressed that the established in Roman law two-steps formula of a legal alienation (*alienatio*), remained in the European codifications until the nineteenth century.

Procedure of purchasing a field with its symbolism described in the Book of Jeremiah (32:9–14) of the Old Testament, is confirmed by the findings of papyri from Elefandid, the Jewish colony near the Nile. It consisted on the fact that the same contract was recorded twice on one tab in such a way that it was possible to roll up one part, which was then tied with a cord and sealed, while the second part of the papyrus of repeated content of the contract was still available. This way of concluding the contract gave interested sides the possibility of its free reading, while on the other hand guaranteed exclusion of any possible interference in its contents. These rolls were stored in clay vessels, "to survive for a long time"[56].

CHOSEN EXAMPLES OF REAL ESTATE REGISTERS IN THE MEDIEVAL EUROPE

During the, so-called, vulgarization[57] of Roman law (IV–V century AD), in the Germanic countries the act of transferring the right of ownership of the property consisted of two necessary acts written down in the presence of witnesses, one of which contained a statement made by the seller, so called, release (*resignatio*), and a statement of the purchaser about taking over the object of a transaction (acquittance), and the second was a contract giving the sold goods to the buyer (*Gewere*). Action of giving the transfer documents in the presence of witnesses (*traditio per cartam*) was thus a sufficient condition for its legal validity, just as it did in Justinian times in which it was commonly practiced to give in public only a statement of the seller to the buyer (*traditio instrimenti*). It was reduced to a symbolic release of "substitute" of the subject contract, making the act of transferring

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[55]   Quote of T. Stawecki, *Real estate registers...*, page 175.

[56]   *Bible for everyone. Volume VII*, red. W. Chrostowski, Kielce 2004, page 262.

[57]   This period of law development dating from Constantine the Great to Justinian (from the word: *vulgaris* – folk, common). This term is associated, among others the collapse of the Western Roman Empire in 476, and a period in which Roman law was taken over by the incoming barbarian tribes that were becoming part of the empire and was simplified and distorted – quote of K. Kolańczyk, *op. cit.*, page 77–80.

the right of ownership "fictional" (*traditio ficta*)[58], without the element of physical release of things to purchaser.

In medieval Franconian law (ninth century) there was another principle introduced. It stated that evidence for transferring the ownership of thing (in addition to the acts of *traditio cartae* character) can be played byt documents (certificates) called "notitia" (*memoratorium*) confirming the fact that the transaction was successfully completed.

Later, in some German cities, contracts for transfer of ownership of the property written in a court or the city council were disclosed in special books. Those contracts adopted the principles of probative value for the entry disclosed within, which has become a condition for effectiveness of activities carried out in this field.

It should be noted that adopted system of registration of activities related to disposal of property rights has become the prototype for the later ground registers (real-state registers). It is worth emphasizing that such records could be "available to anyone who questioned or checked the contract"[59]. Adopted principle meant that the acts of disposal made without the involvement of the court were not effective. The court has become the guarantor of the contract, as well as the institution responsible for issuing opinions in uncontested matters[60].

In medieval Europe, during the period of feudalism, the disposal of right of ownership to property was held compulsorily in the presence of senior, whose social position was to ensure the validity of the transfer of feudal rights[61] from one vassal to another. The ceremony of fiefs transfer, called investure, in its essence lies in the fact that the person interested (vassal) purchased the rights to the real estate from the senior rather than directly from another vassal (the previous wielder). Character of investure made it the institution comparable to the *traditio ficta* in the matter of public disclosure of the act of transferring the power over the property. In the cases where the transfer of possession took place without the participation of senior, the validity and effectiveness of this activity was dependent on its public disclosure, as exemplified by the German institution of *Gewera*. In the initial period the public disclosure of transferring the power over the property was limited to oral statements made by the former holder in the customarily indicated spot. In the later period, this custom has been replaced by the formal duty of disclosure by the former holder the act of disposal of possessed right in the relevant register[62].

In medieval England, the first official property registers, called "Books of the terrible court" (*The Domesday Book*), were established on the basis of the results of feudal census performed in the years 1085–1086. Judges appointed by the William the Conqueror wrote down data allowing to determine to whom the monarch granted the right to have a particular estate, the amount of outstanding fief to the sovereign, which on this basis was subject to execution[63]. Adopted system of registers also allowed disclosure of their

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[58]   Quote of K. Kolańczyk, *op. cit.*, page 302.
[59]   Por. H.J. Berman, *Law and Revolution. Evolution of the western legal tradition*, Warsaw 1995, page 438.
[60]   Quote of T. Stawecki, *Real estate registers…*, page 177.
[61]   The fief law is a medieval customary law shaping the relationship between senior and vassal.
[62]   Quote of P. Dąbkowski, *Lien law in Saxon, Swabian and German mirrors, Studyum the German law of history*, Lvov 1913, page 70 [in:]: T. Stawecki, *Real estate registers…*, page 175.
[63]   K. Krasowski, B. Lesiński, K. Sikorska-Dzięgielewska, J. Walachowicz, *op. cit.*, s. 71; quote of T. Stawecki, *Real estate registers…*, page 181.

institutions (alienation) of transferring the right of ownership in exchange for securing the debt on the property, which – as a system solution – could be a prototype of today's land mortgage (*mortgage*) [64].

However, such a register was not up to date to transfer the right of possession[65]. In practice the solution has been used (*libery of sesin*) modeled on the institutions of the Roman *traditio* or Germanic *Gewere*, in which the element of actual release of things, having often the character of ceremonial transfer of the symbol associated with the property to the purchaser (for example in the form of lumps of earth, twigs of trees, cross, etc.), constituted for the effectiveness of operation. Sometimes there was an act (*deed*) written in Latin describing the activity of delivering the goods to the buyer, which documented the course of the ceremony, testified that it took place and specified the boundaries of the sold property. There was a concept of *sesin* formed during the feudal period which in its original form was closer in meaning to the institution of possession (*possessio*) than ownership (*dominium*). The concept changed with time, which in the thirteenth century led to independent form of "possession of property" (*freehold estate*), and later on it converted into the property defined as a *comman law* and a number of weaker forms of possession (*non-freehold*)[66].

The need to protect the interests of people possessing real estates, from their unauthorized removal, led to the situation where people began to record rights resulted from the concluded contracts in court records, which contributed to the creation of institution of wielding on a basis of entry to court acts (*copyhold*), and thereafter (from the fifteenth century) to develop systems to record the acts of transferring the right of ownership.

Based on the initiative of Henry VIII, the parliament of England accepted the law: *The Statue of Use* and *The Statue of Enroments* in 1535, to organize the existing state resulting from the practice of informal transfer of rights to use real estate (*ces tui que use*). It gave its holder the title to beneficial use (*beneficial interest property)*. The solution was adopted, and users have been given the right of legal ownership (*legal owner*). To prevent the similar cases in the future occurrence, the principle of mandatory registration of act describing the transfer of property (*ded*) in *cort of record* in Westminster or any other public office designated for that purpose was introduced, within the period of six months, beyond which – if not registered – the contract became ineffective[67].

The accepted model for transfer of the property was continued with some modifications until the liquidation of feudal property (the end of the seventeenth century)[68]. During that time the changes made were related to expropriation of existing wielders resulting from the ongoing reform of consolidating land property(fencing the area). New forms of land trust (*trust*) developed in that time above all institution of alienation, as an effective

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[64] Quote of T. Stawecki, M. Tomaszewski, F. Zelder, *The Law on registered pledges and pledge registers. Commentary*, Warsaw 1997, page 178, 183–187, 211–213, 222.

[65] In the feudal period in England they did not distinguish, as in Roman law, the concept of ownership (*dominium*) and possession (*possessio*) of property. This system was based on the concept of wielding the property by the vassal. There were no alodial ownership, that is, free from feudal burdens and obligations (fief).

[66] Quote of S. Rudnicki, *Systems of land registers and material provision on real estate property in most of European countries,* "Rejent" 1995, nr 11, page 28.

[67] *Ibidem*, page 27, 55.

[68] This is the period of the English revolutions that took place in the years 1640–1660 and 1688–1690.

method of securing debt on the property[69]. Constitutional changes carried out at the same time reinforced the very notion of ownership right, which in common perception began to be treated as absolute and inviolable (holy), thus weakening in practice the formal requirements related to the obligation of registration of the sale acts. This contributed greatly to undermining the credibility of public institutions (courts) in which the records of land properties were gathered.

In medieval Europe, influence of Roman law on the shaping of the rules governing the procedure for transferring rights to property were also seen on the example of southern lands of France, where the *traditio* institution has survived until the time of the Napoleonic Code (1804). However, the northern provinces of France were under the influence of Germanic customary law (known as *pays de coutumes*)[70], which in the later period was replaced by contractual clauses transformed with time into a formal legal obligation to register[71] activities that disposing the real estate and its public disclosure[72]. In Brittany the announcement about the conducted transaction was provided by the buyer of the property three times on Sunday, every seven or fourteen days. If at that time no one raised any objections to the content of the contract, the purchaser or creditor rights were protected. In modern times in some provinces of southern France, the system was introduced already; derived from the times of inventure, which imposed an obligation to disclose in the registers kept at the court any changes resulting from operations of transferring the right to property, laid down the supreme position of the transferor (senior) in the contract, and also introduced – as a rule – protection of the purchaser rights, who was first to registered the contract, which would serve the legalization of conducted activities. This system - in a modified form – was introduced throughout France, about a hundred years later during the French Revolution.

In medieval Poland, successful acquisition of ownership rights to property required a separate act as proof that the buyer has came into their possession[73]. For this reason the release of land to the buyer was connected to the demarcation of its borders through the inspection on foot or detour on horse, and with the obligation to prepare a detailed written description of them, "which, if necessary, could serve as evidence in litigation"[74]. In the case of less valuable property, this act was sometimes limited to making a sworn statement of the seller in the public (in the presence of witnesses), to transfer the rights to the property and perform activities of a symbolic nature, which ment the releasing of sold thing, for example by putting hat on the buyers head, handing out gloves or green twigs.

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[69] Quote of K. Michałowska, *Trust and fiduciary relationships in English law*, „Kwartalnik Prawa Prywatnego", 1996, nr 2, page 297–298; A. Kędzierska-Cieślak, *Trusteeship. An attempt to determine the legal structures*, PiP 1997, nr 8-9, page 48–49.

[70] Quote of K. Koranyi, *General History of State and Law*, Warsaw 1965, page 195.

[71] Judicial registration was called *nantissement*.

[72] These two different systems were obligatory in France from the ninth to the thirteenth century – quote of K. Koranyi, K. Sójka-Zielińska (description), *Common history of law*, Warsaw 1976, page 195.

[73] Element of releasing the goods at the sale, as a condition of effectiveness of conducted operation, resulted from obligatory in many European countries Romanule principle of *traditio*.

[74] Quote of J. Bardach, *The history of Polish law and State*, Warsaw 1964, page 299.

Agreements on the transfer of land ownership were concluded in written form already about the year 1000[75].

However, with the development of the official registers held in the courts and at the prince's manor in the Polish territories, the importance of such documents decreased.

More importance was given to documents issued directly by the registry offices of princes (for example Crown Matric or Mazowiecka Metric), or disclosed from the register of passed judgments or acts done directly before the court[76].

At "court registers" (*tabulae iudicii*)[77] ran at that time, mentions were recorded about the acts of selling the land committed before a court, so called (Latin *resignatio*). It was treated as a statement of the actual owners of transferring the right to designated buyer, and it was to replace to so-called "institution", consisting on agreeing with the judges the fact of earlier submission of statements concerning the disposal of the rights to the specified thing[78]. There is interesting thing in this records. The judgments of the courts settling the border disputes or established on property rights of protective character, such as the pledge were reported. So conducted city books acquired in time the right to place in them, so called, entries of perpetual nature[79]. They didn't require – to obtain the probative value of the entry disclosed within them – its confirmation on the basis of a document issued from another register, such as the territorial register. However it is worth emphasizing, that the lack of entry revealed in the city books confirming possession of rights to specific property was not a formal barrier to effective transfer of ownership. In such cases, the seller had to obligatorily acknowledge his rights to sold property in the presence of witnesses[80].

REJESTRY NIERUCHOMOŚCI I SPOSOBY OZNACZANIA GRANIC WŁASNOŚCI – OD CZASÓW NAJDAWNIEJSZYCH DO ŚREDNIOWIECZA W EUROPIE

Streszczenie. W artykule przedstawione zostało zagadnienie dotyczące formowania się norm prawa zwyczajowego a następnie stanowionego, na przestrzeni wieków, poczynając od czasów najdawniejszych aż do okresu średniowiecza w Europie, ustalających zasady oznaczania granic nieruchomości gruntowych, trybu dokonywanych czynności przeniesienia własności, jak i identyfikowania osób, którym przysługiwały określone uprawnienia do wyodrębnionej powierzchni ziemi, które doprowadziły do powstania pierwszych ksiąg gruntowych, stanowiących pierwowzór współczesnych katastrów nieruchomości i ksiąg wieczystych. Od samego początku powołania tej instytucji prawa, tworzone urzędowe rejestry nieruchomości, służyć miały zagwarantowaniu pewności w obrocie prawnym oraz potrzebom publicznym, związanym w szczególności z poborem podatków gruntowych.

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[75] Quote of Bardach, *op. cit.*, s. 229; Quote of J.W. Bandtke-Stężyński, *The History of Polish Law,* Warsaw 1850*,* page 224.

[76] Quote of T. Stawecki, *Real estate registers...*, page 178.

[77] The first mention of them come to Poland in 1322 – quote of T. Stawecki, *op. cit.*, page 373-374.

[78] Quote of A. Menes, *Getting Started on the land registry*, "Rejent" 1994, nr 4, page 58.

[79] Such powers have acquired in the fifteenth century books conducted by the region of "Great Poland" castles.

[80] Quote of T. Stawecki, *Real estate registers...*, page 179.

Utworzenie instytucji rejestrów nieruchomości spowodowało, że określona część powierzchni ziemi, odpowiednio oznaczona i ujawniona w księgach gruntowych, nabierała cech właściwych dla rzeczy materialnej, przez co stawała się towarem, który mógł być przedmiotem zbycia lub zabezpieczenia wierzytelności pieniężnych, co w konsekwencji doprowadziło do wykształcenia się w prawie antycznym instytucji hipoteki, która recypowana została, z pewnymi modyfikacjami, do prawa rzymskiego a następnie do kodyfikacji innych średniowiecznych państw europejskich.

ALGORYTMY EWOLUCYJNE W ZASTOSOWANIU DO ROZWIĄZYWANIA WYBRANYCH ZADAŃ OPTYMALIZACJI

Józef Gil

Streszczenie. W pracy rozpatrywano dwie strategie ewolucyjne ($\mu + \lambda$) oraz (μ, λ) wykorzystywane do rozwiązywania skomplikowanych problemów optymalizacji numerycznej. Omawiane w pracy strategie, inspirowane ewolucją biologiczną i genetyką, operują na populacjach o liczebności μ i λ potencjalnych rozwiązań z deterministyczną procedurą selekcji. Poprawność działania strategii jako poszukiwanie globalnego minimum funkcji kryterium przedstawiono na przykładzie minimalizacji funkcji Ackleya oraz estymacji parametrów funkcji regresji II rodzaju.

Słowa kluczowe: strategie ewolucyjne, optymalizacja numeryczna

WSTĘP

Jednym z trzech kierunków rozwoju tzw. *symulowanej ewolucji* obok *algorytmów genetycznych* i *programowania ewolucyjnego* stanowią strategie ewolucyjne jako metody rozwiązywania zagadnień optymalizacji. Procedury strategii optymalizacji działają na zasadzie naturalnej ewolucji. Algorytmy ewolucyjne nazywane są również technikami obliczeń ewolucyjnych, które rozumiane w szerszym sensie odbiegają od klasycznego algorytmu genetycznego. Strategie ewolucyjne są często traktowane jako programy ewolucyjne, które operują na zmiennopozycyjnej reprezentacji chromosomów w postaci liczb rzeczywistych.

PORÓWNANIE STRATEGII EWOLUCYJNYCH I ALGORYTMÓW GENETYCZNYCH

Mimo podobieństw w działaniu strategii ewolucyjnych i algorytmów genetycznych istnieje wiele różnic między tymi algorytmami. Obie metody, mimo że każda z nich powstała

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niezależnie, mają cechy wspólne. Zasadnicze podobieństwo stanowi inicjacja, czyli wybór początkowej populacji potencjalnych rozwiązań. Podobieństwo obu metod przejawia się również w procesie selekcji osobników, które przetworzone prowadzą do uzyskania optymalnych lub najczęściej suboptymalnych rozwiązań.

Pierwsza różnica, jak to zasygnalizowano we wstępie, dotyczy sposobu reprezentacji generowanej populacji osobników. Algorytmy genetyczne operują na wektorach binarnych, natomiast algorytmy ewolucyjne działają na wektorach liczb zmiennoprzecinkowych.

Druga różnica jest zawarta w procesie selekcji. Proces selekcji w algorytmie genetycznym polega na wyborze (wybór losowy) z populacji rodzicielskiej osobników najlepiej przystosowanych, przy czym takie osobniki mogą być wybierane kilkakrotnie. Istnieją też przypadki, że nawet niekorzystnie przystosowany osobnik może zostać wybrany. W algorytmie ewolucyjnym procedura selekcji jest deterministyczna. Utworzona zostaje populacja tymczasowa. Nowa generacja osobników zawiera osobniki populacji tymczasowej i najlepsze osobniki populacji początkowej wybierane bez powtórzeń.

Ostatnia istotna różnica między strategiami ewolucyjnymi a algorytmami genetycznymi wynika z kolejności procedur selekcji i rekombinacji (zmiany genów w procesie działania operatorów genetycznych). W strategiach ewolucyjnych w pierwszej kolejności stosuje się procedurę rekombinacji, po czym następuje procedura selekcji. W algorytmach genetycznych obowiązuje odwrotna kolejność, tzn. najpierw stosuje się procedurę selekcji, a następnie zostają zastosowane zgodnie z przyjętym prawdopodobieństwem operatory genetyczne (krzyżowanie, mutacja). Z przedstawionych porównań można skonstatować, że nowy osobnik generowany zgodnie ze strategią ewolucyjną stanowi rezultat krzyżowania dwóch osobników rodzicielskich oraz mutacji. Niektóre wersje strategii ewolucyjnych stosują wyłącznie procedurę mutacji z pominięciem procedury krzyżowania. Należy też dodać, że parametry algorytmów genetycznych są stałe pod względem przyjętych wartości, natomiast w strategiach ewolucyjnych parametry wynikają z procesu adaptacji.

STRATEGIA EWOLUCYJNA (μ+ λ)

Strategia minimalizuje prawdopodobieństwo osiągania minimum lokalnego końcowego rozwiązania, co stanowi jej podstawową zaletę. Przedstawimy ten algorytm na przykładzie minimalizacji funkcji $f(x_1, x_2) = x_1^2 + x_2^2$ [Rutkowski 2009]. Jako początek algorytmu zostaje wygenerowana populacja początkowa **P** (w przykładzie liczebność populacji ograniczona), złożona z μ = 4 osobników generowanych losowo, reprezentowanych przez dwuelementowe wektory $x = [x_1, x_2]^T$ (x – wektor parametrów dla rozwiązywanego problemu) i σ = $[\sigma_1, \sigma_2]^T$ (σ – wektor parametrów mutacji) (tab. 1).

Tabela 1. Populacja **P**
Table 1.   Population **P**

Numer osobnika Number of individual	x_1	x_2	σ_1	σ_2	$f(x_1, x_2)$
1	0,82	0,17	1	1	0,69
2	0,47	0,12	1	1	0,24
3	0,12	0,00	1	1	0,02
4	-0,36	-0,72	1	1	0,65

Kolejnym etapem algorytmu jest utworzenie poprzez reprodukcję populacji tymczasowej **T** o liczebności λ osobników, przy czym λ ≥ μ. Reprodukcja stanowi wynik losowego wyboru λ osobników z populacji **P** (losowanie ze zwracaniem) w celu utworzenia populacji tymczasowej **T** (tab. 2). Zauważmy, że do populacji T przeszły chromosomy oznaczone jako 2 i 3.

Tabela 2. Populacja **T**
Table 2.   Population **T**

Nr osobnika Number of individual	x_1	x_2	σ_1	σ_2	$f(x_1, x_2)$
1	0,82	0,17	1	1	0,69
2	0,47	0,12	1	1	0,24
3	0,47	0,12	1	1	0,24
4	0,12	0,00	1	1	0,02

Na osobnikach populacji T należy teraz dokonać operacji genetycznych w postaci mutacji chromosomu σ oraz chromosomu (tab. 3 i). Procedura mutacji (zmiana informacji zawartej w genotypie osobnika) przebiega na pojedynczym osobniku według zależności

$$\sigma_i' = \sigma_i \exp(\tau' N(0,1) + \tau N_i(0,1)) , \qquad (1)$$

gdzie: $i=1,2,\ldots,n$, n – długość chromosomu, $N(0,1)$ – liczba losowa z rozkładu normalnego losowana jednorazowo dla całego chromosomu, $N_i(0,1)$ – liczba losowa z rozkładu normalnego losowana dla każdego genu, τ i τ' – parametry strategii ewolucyjnych, które mają istotne znaczenie dla uzyskania zbieżności algorytmu do rozwiązania. Wartości parametrów otrzymuje się na podstawie wzorów:

$$\tau' = \frac{C}{\sqrt{2n}} , \qquad\qquad \tau = \frac{C}{\sqrt{2\sqrt{n}}} , \qquad (2)$$

w których najczęściej przyjmuje się wartość $C = 1$.

Tabela 3. Mutacja chromosomu σ poszczególnych osobników populacji **T**
Table 3.   Mutation of the chromosome σ of particular individuals of the population **T**

Nr osobnika Number of individual	$N(0,1)$	Gen 1 Gene 1				Gen 2 Gene 2			
		σ_1	$N_1(0,1)$	$\exp(\tau'N(0,1) + \tau N_1(0,1))$	σ'_1	σ_2	$N_2(0,1)$	$\exp(\tau'N(0,1) + \tau N_1(0,1))$	σ'_2
1	-0,30	1	-0,23	0,75	0,75	1	0,87	1,44	1,44
2	0,41	1	1,81	3,61	3,61	1	-0,35	1,00	1,00
3	-0,28	1	-1,58	0,34	0,34	1	0,52	1,18	1,18
4	0,05	1	-0,65	0,70	0,70	1	-1,13	0,52	0,52

Na podstawie obliczonych nowych zakresów mutacji σ'$_i$, kolejne chromosomy x_i przyjmują wartości zgodnie z formułą

$$x_i' \ = \ x_i + \sigma_i' N_i(0,1) \ ,\tag{3}$$

gdzie $N_i(0,1)$ reprezentuje liczbę losową z rozkładu normalnego, $i = 1, \ldots, n$ (tab. 4).

Tabela 4. Mutacja chromosomu **x** poszczególnych osobników populacji **T**
Table 4. Mutation of the chromosome x of particular individuals of the population **T**

Nr osobnika Number of individual	Gen 1 Gene 1				Gen 2 Gene 2			
	x_1	$N_1(0,1)$	$\sigma_1' N_1(0,1)$	x_1'	x_2	$N_2(0,1)$	$\sigma_2' N_2(0,1)$	x_2'
1	0,82	0,27	0,19	1,01	0,17	-0,30	-0,44	-0,27
2	0,47	0,45	1,61	2,09	0,12	1,25	1,25	1,36
3	0,47	0,75	0,26	0,73	0,12	0,90	1,07	1,19
4	0,12	0,27	0,19	0,32	0,00	0,67	0,35	0,35

Po dokonaniu operacji genetycznych otrzymujemy populację potomną **O** zawierającą chromosomy zestawione w tabeli. 5.

Tabela 5. Nowa populacja **O**
Table 5. New population **O**

Nr osobnika Number of individual	x_1	x_2	σ_1	σ_2	$f(x_1, x_2)$
1	1,01	-0,27	0,75	1,44	1,10
2	2,09	1,37	3,61	1,00	6,22
3	0,73	1,19	0,34	1,18	1,94
4	0,32	0,35	0,70	0,52	0,22

Stosując zasadę działania strategii (μ + λ), nowa populacja **P** zostaje utworzona z najlepszych chromosomów wcześniej wygenerowanej populacji **P** oraz aktualnej populacji **O** (tab. 6).

Tabela 6. Nowa populacja **P**
Table 6. New population **P**

Nr osobnika Number of individual	x_1	x_2	σ_1	σ_2	$f(x_1, x_2)$
1	0,12	0,00	1	1	0,02
2	0,32	0,35	0,70	0,52	0,22
3	0,47	0,12	1	1	0,24
4	-0,36	-0,72	1	1	0,65

Drugą stosowaną strategią jest strategia (μ, λ), której działanie jest prawie identyczne jak strategii (μ + λ). Strategia wymaga jedynie spełnienia warunku (μ > λ), ponieważ nowa populacja **P** o liczebności μ osobników zostaje utworzona z najlepszych λ osobników populacji **O**.

PRZYKŁADY ZASTOSOWAŃ STRATEGII EWOLUCYJNYCH

Sprawdzenie poprawności i efektywności działania algorytmów ewolucyjnych zrealizujemy na podstawie kilku prostych zadań testowych.

Przykład 1. W pierwszym zadaniu będziemy poszukiwać minimum 2-wymiarowej funkcji Ackleya {Rutkowski 2009]. Z postaci funkcji

$$f(x_1, x_2) = -20\exp(-0{,}2\sqrt{0{,}5(x_1^2 + x_2^2)}) - \exp(0{,}5\cos(2\pi x_1) + \cos(2\pi x_2)) + 20 + e \quad (4)$$

oraz jej wykresu wynika, że funkcja osiąga minimum globalne $f(x) = 0$ w punkcie $x = 0$. Przyjmując $n = 2$ przy ograniczeniach $-5{,}0 \le x_1 \le 5{,}0$, wygenerowano 50 wartości populacji początkowej. Po zrealizowaniu 50 generacji uzyskano zbliżenie do wartości poszukiwanego minimum w postaci funkcji przystosowania $f(x_1, x_2) = 0{,}047$ dla $x_1 = -0{,}013$ i $x_2 = -0{,}006$. Przykład należy uzupełnić uwagą, że w kolejnych krokach algorytmu zostaje utracona informacja na temat poprzedniego najlepszego rozwiązania, co zapobiega utknięciu algorytmu w minimum lokalnym.
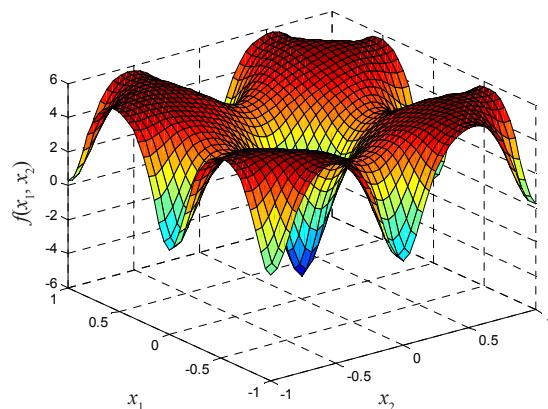
Rys. 1. Wykres funkcji dwuwymiarowej Ackleya
Fig. 1. Diagram of the two-dimensional Ackley function

Przykład 2. W wyniku przeprowadzonego eksperymentu uzyskano empiryczny zbiór siedmiu punktów zlokalizowanych na osi cięgna (tab. 7) [Nowak 2003].

Tabela 7. Wyniki pomiaru krzywej zwisu cięgna
Table 7.   Measurement results of the sag curve of the strand

Nr punktu No. point	1	2	3	4	5	6	7
X	1,5	3,5	5,5	7,5	9,0	10,5	12,0
Y	1,5	2,5	4,0	6,0	7,5	10,0	12,5

Kształt krzywej zwisu cięgna pod wpływem własnego ciężaru opisuje krzywa łańcuchowa wyrażona równaniem (patrz zamieszczony niżej wykres) [Adamczewski 1992]. Zadanie polega na estymacji p parametrów krzywej regresji (łańcuchowej) z zachowaniem warunku $[v_y^2] = \min$. Parametry:

k – parametr wykorzystywany do obliczenia siły naciągu w cięgnie,

a, b – stałe translacji początku układu współrzędnych

xoy względem początku układu współrzędnych pomiarowych XOY.
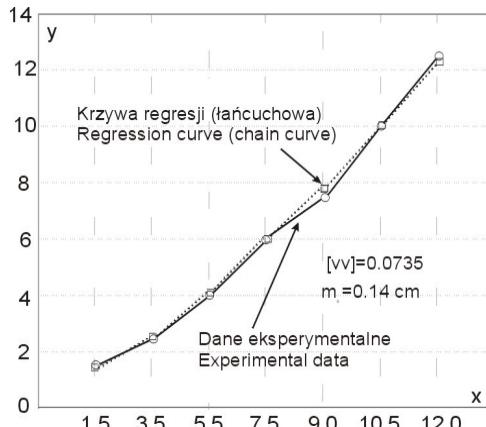
Rys. 2. Regresja jednowymiarowa
Fig. 2. One-dimensional regression

W wyniku działania algorytmu ewolucyjnego uzyskano: k = 10,5102, a = 2,5572, b = 9,7930. Krzywą zwisu aproksymowano również za pomocą modelu regresji krzywoliniowej, opartym na paraboli stopnia drugiego. Dokładności aproksymacji, charakteryzowane błędami średnimi na podstawie oszacowanych parametrów strukturalnych obu modeli regresji, nie wykazały znaczących różnic.

Przykład 3. Dany jest zbiór punktów $[x_i, y_i]$ dla i = 1, 2, 3. Będziemy poszukiwać parametrów funkcji regresji II rodzaju, bowiem większość modeli regresyjnych to modele liniowe, których liniowość daje się relatywnie łatwo zbadać z punktu widzenia parametrów. Przyjęto założenie, że współrzędne punktów zostały wyznaczone empirycznie. Na rysunku 3 została przedstawiona prosta regresji zwykłej oraz prosta regresji ortogonalnej.

Dla ustalonego deterministycznego wektora **x** estymacja parametrów prostej regresji zwykłej $y\,|\,x$ polega na rozwiązaniu zadania $\min_{y,p}(Y - Y_{obs})^T(Y - Y_{obs})$ z uwzględnieniem restrykcji $F((x, y, p) = 0$ (p – parametry zadania). Rozpatrując regresję ortogonalną, estymacja parametrów prostej regresji $F((x, y, p) = 0$ wymaga rozwiązania zadania $\min_{x,y,p}(X - X_{obs})^T(X - X_{obs}) + (Y - Y_{obs})^T(Y - Y_{obs})$ z zachowaniem restrykcji $F((x, y, p) = 0$. Z rysunku 3 można odczytać, że w przypadku regresji ortogonalnej uzyskano suboptymalne rozwiązanie zadania.
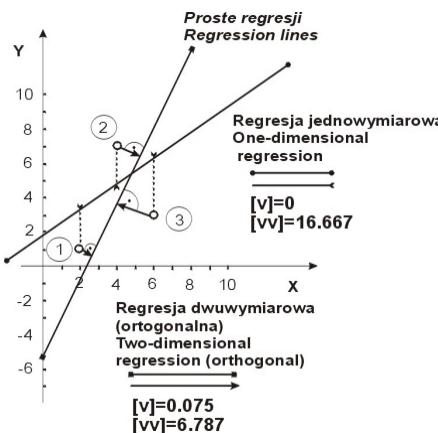
Rys. 3. Regresja dwuwymiarowa
Fig. 3. Two-dimensional regression

Przykład 4. W zastosowaniach w dziedzinie ekonomii, zagadnieniach przyrodniczych oraz technicznych, gdzie występują zmienne jako wielkości fizyczne (np. czas, temperatura), większe znaczenie przypisuje się regresji nieliniowej często ortogonalnej. W związku z tym, dany jest dwuelementowy zbiór punktów o określonych współrzędnych $[x_i, y_i]$, $i = 1, 2$. Należy dokonać aproksymacji danego zbioru punktów parabolą o postaci $f(x) = ax^2$, która aproksymuje zbiór $[x_i, y_i]$, $i = 1,2$ w sensie euklidesowym. Wykres paraboli oraz wyniki obliczeń zostały przedstawione na rysunku 4.
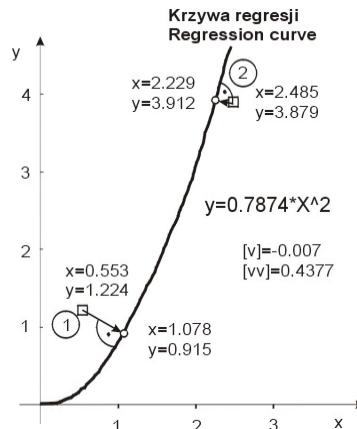
Rys. 4. Krzywa regresji
Fig. 4. Regression curve

Zadanie ma charakter dydaktyczny (zadanie Bahra), dla którego przypadki formułowania modelu wyrównawczego zostały przedstawione w pracy Nowak [2003].

PODSUMOWANIE

Strategie ewolucyjne należą do najważniejszych metodologii obliczeń ewolucyjnych z zachowaniem deterministycznych metod wyboru. Dla strategii ewolucyjnych udowodniono twierdzenie o zbieżności [Arabas 2001], które mówi, że dla dużej liczby poszukiwań uzyskuje się optimum globalne optymalizowanego kryterium z prawdopodobieństwem 1. Na podstawie tego twierdzenia nie można jednak uzyskać informacji o prędkości zbieżności algorytmu do oczekiwanego optymalnego rozwiązania.

W tej kwestii pewnym utrudnieniem w implementacji algorytmu ewolucyjnego jest sformułowanie warunku zatrzymania. Najprostsza metoda polega na wykonaniu ustalonej liczby generacji nowych zbiorów parametrów zadania jako punktów przestrzeni poszukiwań. Wada tej metody ujawnia się w braku kontroli jakości uzyskanego rozwiązania. Stąd częściej stosuje się zatrzymanie pracy algorytmu po uzyskaniu zadowalającej wartości zdefiniowanej funkcji przystosowania [Łęski 2008]. Algorytmy ewolucyjne są łatwe do stosowania, ponieważ nie istnieją ograniczenia na optymalizowane kryterium.

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EVOLUTIONARY ALGORITHMS USED FOR SOLVING SELECTED OPTIMIZATION TASKS

Abstract. The paper discusses two evolutionary strategies ($\mu + \lambda$) and (μ, λ) used for solving complicated problem s of numerical optimization. The strategies discussed in the paper, inspired by biological evolution and genetics, operate in populations of the sizes μ and λ of potential solutions with a deterministic selection procedure. The correctness of the operation of the strategy as a search for a global minimum of a criterion function is exemplified by the minimization of an Ackley function and the estimation of parameters of a regression function of the second kind.

Key words: evolutionary strategies, numerical optimization

MAPPING SPATIAL DISTRIBUTION OF CHOSEN ENVIRONMENTAL CHARACTERISTICS FOR AGRICULTURAL USE IN LOWER SILESIA

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Abstract. Spatial statistics allows to assess geographic distribution of phenomena – its concentration, magnitude and orientation of dispersion as well regularity or trends in occurrence within a space. The paper presents adaptation of point-based methods to measure spatial distribution of areal phenomena that concern agriculture: area of agricultural land, area of fertile agricultural land and soil pH. The source data in a form of chorochromatic maps (e.g. a vector soil map) are processed to 1 x 1 km grid data with use of the algorithm created in Model Builder.

The research area – Lower Silesia – characterizes various environmental conditions that results in changeability of agricultural land productivity. Spatial statistics performed for a whole region would bring only global information on spatial distribution. Hence the Authors propose to conduct analysis within subareas that depict local changeability of studied phenomena. As the research is conducted in agricultural context, the subareas of similar agricultural land areas are created regarding the administrative units. Spatial distribution is described by: mean centre, standard distance and standard deviational ellipse. All three measures are weighted by a variable (i.e. the intensity of the phenomenon) as spatial distribution is not only about location, but the value of the phenomenon in particular location is important.

Measures of spatial distribution drawn on a map yields clear and usually easy to interpret information on spatial character of a phenomenon. In some cases it may be useful to present these qualitative characteristics complemented with another type of cartographic visualization (e.g. a choropleth map. This paper presents maps about the application of spatial distribution measures into assessment of agricultural land productivity in the research.

Key words: spatial distribution, centrographic method, mean centre, standard distance, standard deviational ellipse

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INTRODUCTION

The visual analysis of phenomena presented on maps allow for general assessment of geographic distribution. To discover patterns in spatial relationships and local characteristics of phenomenon intensity one requires quantitative measures. Implementation of statistical analysis of spatial data in GIS software allow – besides calculating the measures – to visualize the outcomes. Various spatial statistics techniques to assess geographic distribution of phenomena are available in the literature [Anselin 1999, Cliff and Ord 1981, 1992, Earickson and Harlin 1994, Ebdon 1985, Jażdżewska 2003, Magnuszewski 1999, Miller 2004, Urbański 2008]. However, the majority of them is used for distribution measurements of point data [Longley et al. 2006]. The paper presents adaptation of point-based methods to measure spatial distribution of areal phenomena connected with agriculture. The research area – Lower Silesia region (Fig. 1) – characterizes various environmental conditions that results in changeability of agricultural land productivity. It is located in south-western Poland and comprises of lowlands of high potential agricultural use as well as mountainous areas representing less-favoured areas for agricultural production. The relief variability translates also on soil, water and climate conditions.

Spatial statistics analysis for a whole region would bring only global information on geographic distribution. Hence it is proposed to conduct analysis within subareas that depict local changeability of studied phenomena. As the research is conducted in agricultural context, the subareas of similar agricultural land areas are proposed (Fig. 1). The boundaries are created regarding the administrative borders of the counties.
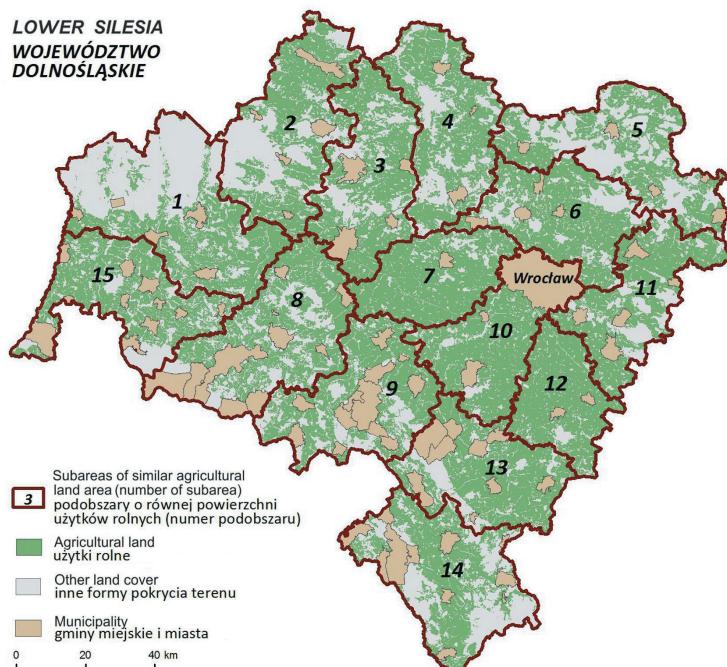
Fig. 1. Subareas of similar agricultural land area against the background of agricultural land
    Rys. 1. Podobszary o zbliżonej powierzchni użytków rolnych na tle użytków rolnych

SOURCE DATA AND ITS PROCESSING

In this study chosen phenomena that affects agricultural productivity are taken under consideration: area of agricultural land, area of fertile agricultural land and soil pH. The agricultural land are extracted from vector soil map of Lower Silesia in a scale of 1 : 25 000 (source: Regional Centre of Geodetic and Cartographic Documentation (WODGIK)). The map contains also information on land potential productivity discerned as 13 types on arable lands and 3 types on meadow and grass-land. Determination of the types is based on soil type, its physical and chemical parameters, relief, climate and water conditions [Witek 1993]. The index of quality and agricultural productivity of land describes each type and ranges from 18 to 94 points within arable lands and from 20 to 80 points within meadows and grasslands [Stuczyński et al. 2007]. The fertile agricultural land are determined based on the index values and detailed description of each type [Stuczyński et al. 2007]: over 64 points for arable lands and 80 points for meadows and grasslands. The distribution of fertile land on against the agricultural land is presented in Figure 2.
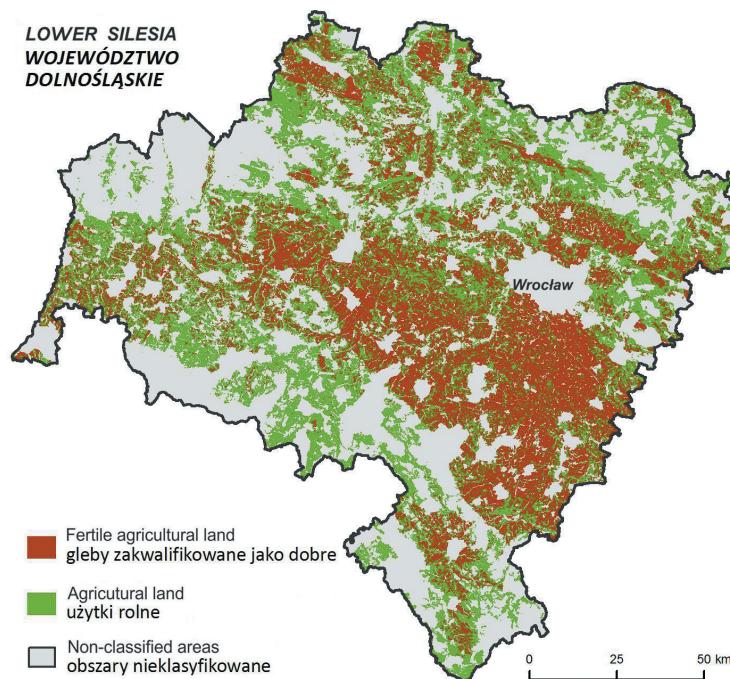
Fig. 2. Distribution of high fertile agricultural land on the background of agricultural land
Fig. 2. Rozmieszczenie gleb zakwalifikowanych jako dobre na tle użytków rolnych

Information on soil pH is derived from the map presenting physical and chemical parameters of agriculturally used soils in the scale of 1 : 25 000 [Stuczyński et al. 2007]. Figure 3 shows the distribution of soil pH within the research area. pH of soil, which is optimal for crop production (5.5–7.2) is under consideration in the further research.
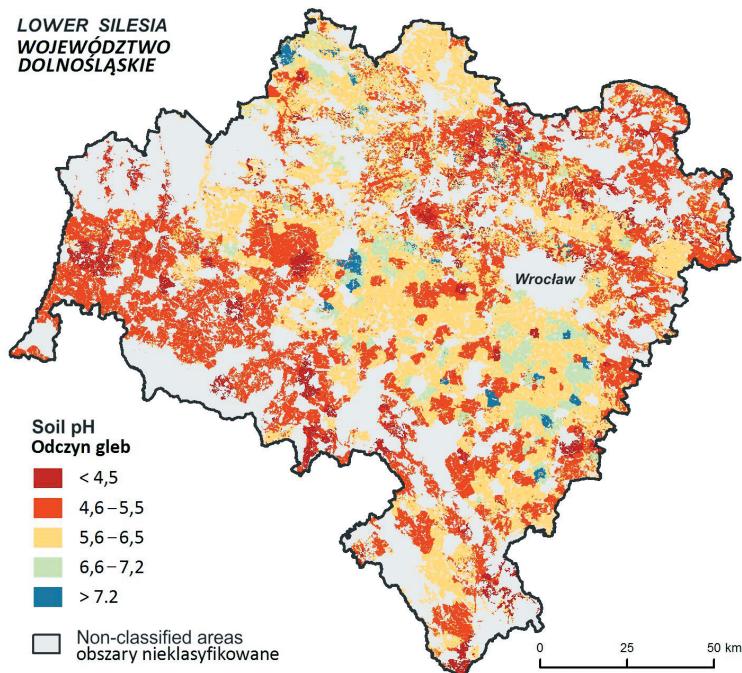
Fig. 3. Distribution of soil pH
Rys. 3. Rozmieszczenie odczynu gleby

Measuring spatial distribution requires transformation from qualitative approach (nominal scale) to quantitative scale. The continuous or semi-continuous phenomena (e.g. agricultural land; soil pH) are changed into discrete data using grid of 1 x 1 km. The geometric reference units are created according to division of Poland in TEMKART system [Podlacha 1986]. The size of grid is adopted to the study area and impacts on the accuracy of analysis that has been an issue in the separate research [Klimczak at el. 2006]. The constructed algorithm of data geoprocessing has been created in ModelBuilder in ArcGIS (Fig. 4). It enables automatic conversion of qualitative data presented on choro-chromatic map (e.g. a soil map) into a database composed of grid units with qualitative attributes. The model has several parameters (letter p in a scheme) that make it useful for any source data, any study area and any reference unit.
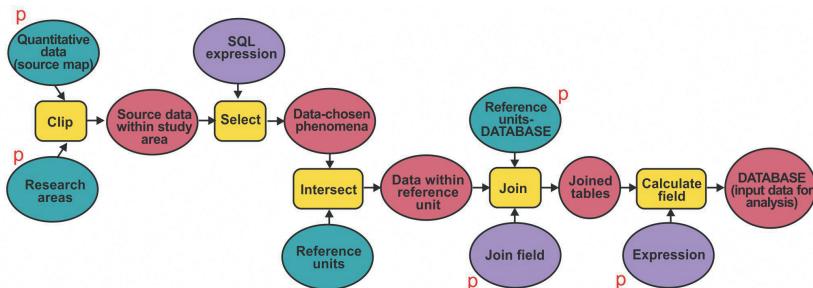
Fig. 4. Algorithm of data processing from qualitative to quantitative approach
Fig. 4. Algorytm przetwarzania danych wyrażonych w skali jakościowej na ilościową

The Lower Silesia covers 20 936 reference units of size 1 x 1 km (i.e. database features). The three characteristics calculated as the result of geoprocessing (see Fig. 4) are the percentage share of: agricultural land areas, high fertile agricultural land areas, optimal soil pH areas in the reference unit. The number of features considered in the analysis varies depending on a phenomena: 14 705 (agricultural land), 12 306 (high fertile agricultural land areas), 10 659 (optimal soil pH areas).

Methodology

Spatial distribution is not only about location, but the intensity of the phenomenon in particular location is important. The spatial measure that regards the attributes' values of the features is weighted mean centre. The weighted mean centre called also a geographic centre is two-dimensional average weighted by a variable and it is calculated according to the following formula [Magnuszewski 1999]:

$$\bar{x} = \frac{\sum\limits_{i=1}^{n} w_i x_i}{\sum\limits_{i=1}^{n} w_i} \qquad \bar{y} = \frac{\sum\limits_{i=1}^{n} w_i y_i}{\sum\limits_{i=1}^{n} w_i} \qquad (1)$$

where $\bar{x}$, $\bar{y}$ – centre (centroid), w_i – value of a variable (attribute value) x_i, y_i – coordinates of a feature, n – number of features.

The measure basically relates to the concentration of points (x and y coordinates). In the paper, the centrographic method is adopted to polygon features with the assumption that the centroid's coordinates of reference units are taken into account.

The information on geographic centre of the phenomenon is complemented with measure of its dispersion from a mean centre expressed by a standard distance. It is a two-dimensional equivalent to standard deviation and is calculated as follows [Jażdżewska 2003]:

$$r = \sqrt{\frac{\sum\limits_{i=1}^{n} w_i (x_i - \bar{x})}{\sum\limits_{i=1}^{n} w_i} + \frac{\sum\limits_{i=1}^{n} w_i (y_i - \bar{y})}{\sum\limits_{i=1}^{n} w_i}} \qquad (2)$$

where $\bar{x}$, $\bar{y}$ – centre (centroid), w_i – value of a variable (a phenomenon) x_i, y_i, – coordinates of a feature, n – number of features.

Determination of weighted mean centres and standard distances within subareas and their visualization on a map allow for analysing local trends in spatial distribution. Moreover, the utility of the mean centre is for comparing spatial distribution of different phenomena and may bring information on correlation between them.

The aforementioned spatial measures yields information on magnitude of dispersion, but not its directions. In order to assess the directional trends the standard deviational ellipse is used. The angle of rotation of an ellipse is given as [Ebdon 1985]:

$$\text{tg}\alpha = \frac{\sum x_i^{'2} - \sum y_i^{'2} + \sqrt{\left(\sum x_i^{'2} - \sum y_i^{'2}\right)^2 + 4\left(\sum x_i' y_i'\right)^2}}{2\left(\sum x_i' y_i'\right)^2} \tag{3}$$

where: $x' = x - \overline{x}$, $y' = y - \overline{y}$

The axes of the ellipse are defined as the standard deviation of the x coordinates and y coordinates from the mean centre:

$$\sigma_x = \sqrt{\frac{\left(\sum x'^2\right)\cos^2\alpha - 2\left(\sum x' y'\right)\sin\alpha\cos\alpha + \left(\sum y'^2\right)\sin^2\alpha}{n}} \tag{4}$$

$$\sigma_y = \sqrt{\frac{\left(\sum x'^2\right)\sin^2\alpha - 2\left(\sum x' y'\right)\sin\alpha\cos\alpha + \left(\sum y'^2\right)\cos^2\alpha}{n}} \tag{5}$$

It should be noticed that the standard deviational ellipse may be calculated using either the locations of the features or using the locations influenced by an attribute value associated with the features (w_i). In the research, the latter one – weighted standard deviational ellipse – is used and allows to see whether the distribution of the phenomena is elongated and hence has a particular orientation.

RESULTS

Measures of spatial distribution drawn on a map yields clear and usually easy to interpret information on spatial character of a phenomenon. In some cases it may be useful to present these qualitative characteristics complemented with another type of cartographic visualization. Figure 5 shows the localization of mean centres and standard distances calculated for high fertile agricultural lands on the background of the choropleth map presenting percentage share of these lands in a reference unit. The essential concentration of high fertile agricultural lands may be noticed in eight of fifteen subareas: 6, 7, 8, 9, 10, 12, 13, 14. Whereas the biggest dispersion characterizes subareas number: 2, 3 and 5 located in the northern part of Lower Silesia. What should be stressed out that mapping spatial statistical measures delivers additional information which may be different from visual assessment of studied phenomenon based on a choropleth map. One may notice similar intensity of the high fertile agricultural lands in 2 and 8 subareas, however only the location of the mean centre shows the place where the phenomenon is concentrated and standard distance points that the fertile lands are more condensed in the 8th subarea than in the 2nd.
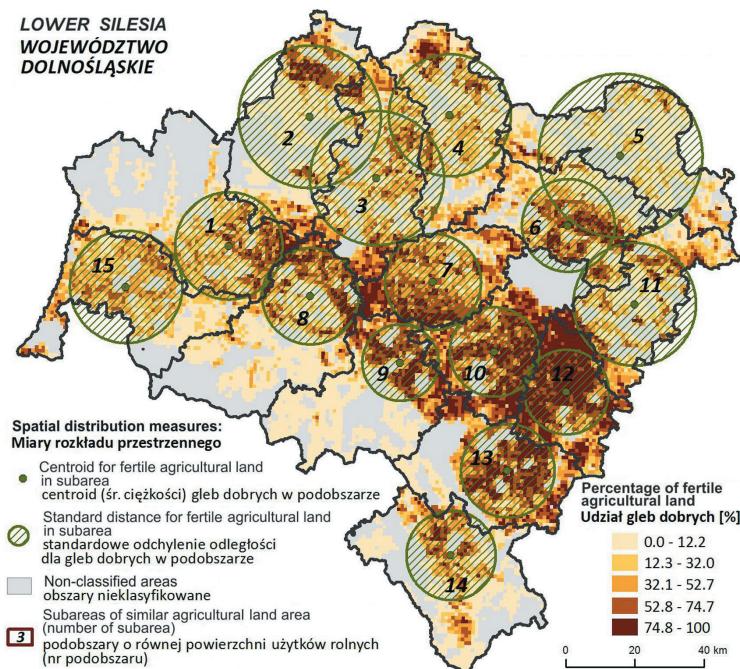
Fig. 5. Spatial distribution measures for high fertile agricultural land
Fig. 5. Miary rozkładu przestrzennego dla gleb zakwalifikowanych jako dobre

The standard distance shows the degree of dispersion of the phenomenon. In order to see the directions of dispersion which are also valuable characteristics of spatial distribution, the standard deviational ellipse is considered. The figure 6 presents the ellipses for agricultural lands calculated in subareas.

It should be stressed out that due to that fact that parameters of the standard deviational ellipses are related to the size and shape of the subareas, the better solution is to analyse the data within subareas of the similar shape and size. The example of such subareas is proposed in a form of squares of 27 x 27 km created based on the 1 x 1 km grid reference units (Fig. 8). The assumption is to cover the whole Lower Silesia not overestimating the area. However, the choice of size, shape and location of these subareas should be an issue of a further research.

The Authors notice that analysis in subareas – regardless its size and shape – is appropriate and useful for comparing a few phenomena. That is important especially in application studies such as agricultural use of land when various factors are taken into consideration. Presenting a few phenomena on one map delivers information on the possible correlation between them. In order to investigate the correlation in spatial distribution of agricultural lands and the soil conditions, the centroids and standard deviational ellipses are determined for: agricultural land, fertile agricultural land and optimal soil pH (Fig. 7).
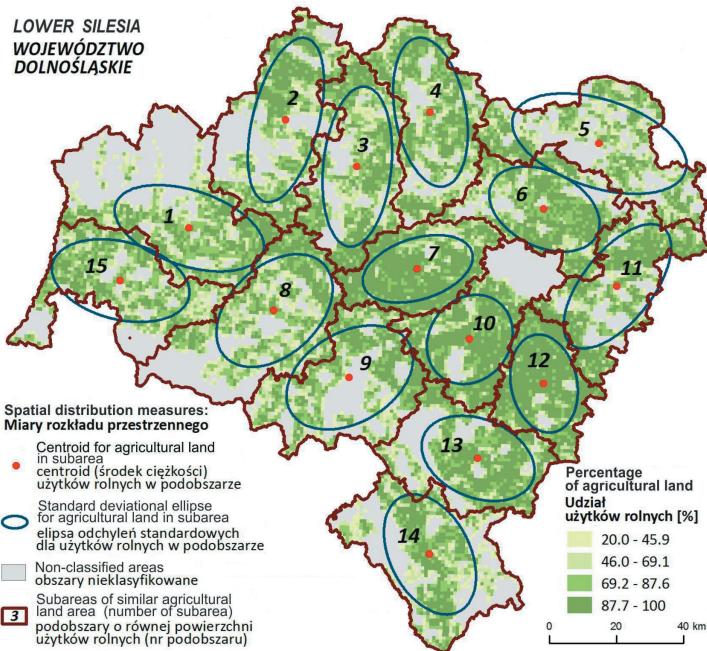
Fig. 6. Spatial distribution measures for agricultural land
Fig. 6. Miary rozkładu przestrzennego dla użytków rolnych
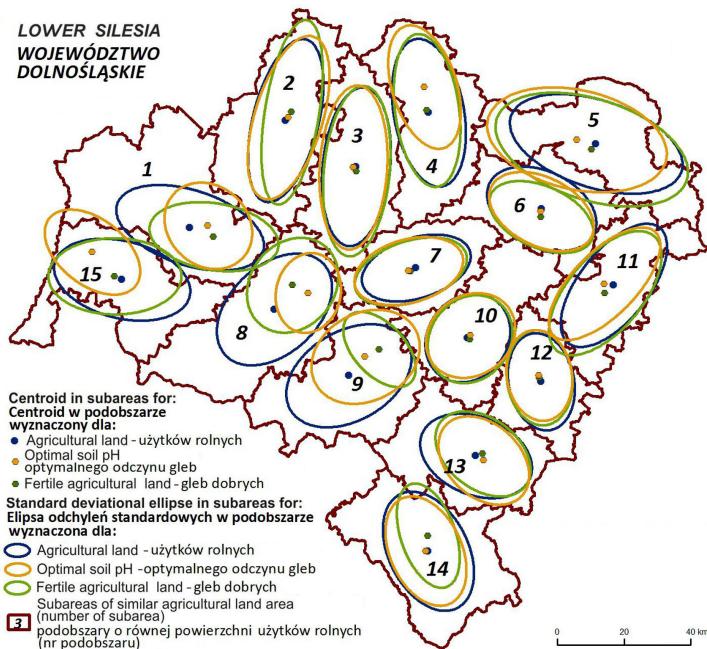
Fig. 7. Comparison of spatial distribution measures for the three phenomena
in subareas of similar agricultural land area
Rys. 7. Porównanie miar rozkładu przestrzennego trzech zjawisk
w podobszarach o zbliżonej powierzchni użytków rolnych

The visual analysis of the outcomes (Fig. 7) leads to conclusion that in some sub-areas (e.g. 7, 10, 12) "geographic centre" (centroid) of agricultural land and favourable conditions for agriculture are corresponding to each other, as well the dispersion and its directions are overlapping. There are also regions where the variability of phenomena within a space is bigger. For instance, 9th subarea – the agricultural land occur within the whole area, while the fertile agricultural land and soil of optimal pH are concentrated in its northern part. Moreover, the directions of dispersion are different: north-east for fertile agricultural land and south-west for optimal soil pH. Similar situation can be observed in the 8th subarea where the concentration of favourable conditions for agriculture are located in the northern part. The 15th subarea is characterized by high fertility of all agricultural land (the ellipses of agricultural land and high fertile agricultural land are nearly overlapping), but the soil conditions are located in the north-west.
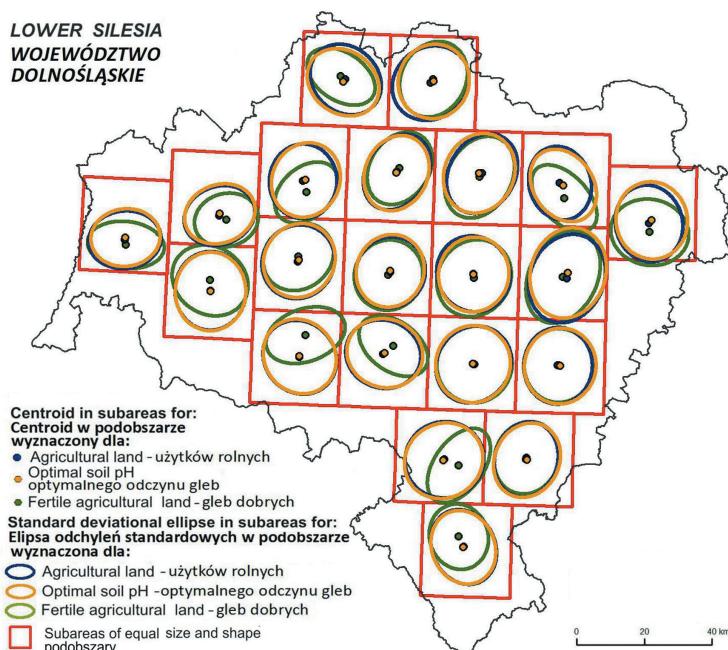

Fig. 8. Comparison of spatial distribution measures
for the three phenomena in subareas of equal size and shape
Rys. 8. Porównanie miar rozkładu przestrzennego trzech zjawisk
w podobszarach o takim samym kształcie i równej powierzchni

The analysis of the same conditions in equal subareas (Fig. 8) confirmed the observations that the most favourable conditions of agricultural land are located in the central part of Lower Silesia (the all three centroids and ellipses are overlapping). There are differences in spatial distribution in the outer subareas, mainly in direction of dispersion of high fertile agricultural land.

CONCLUSION

In analysing the spatial distribution – its concentration or dispersion and their directions – it is essential to map the outcomes. The visualization of location of the "geographic centre" and orientation of the distribution brings additional and useful information on the studied phenomena. The paper presents the application of spatial distribution measures (weighted mean centre, standard distance, deviational ellipse) into assessment of agricultural land productivity in Lower Silesia. In order to analyse the local changeability of the phenomena, the subareas of similar agricultural land area are proposed. The Authors notice that these subareas are more relevant to comparison of different phenomena within the same subarea, than to analyse a phenomenon in a global scale (within whole region). That is due to the fact that the standard deviational ellipse parameters relates to the shape and size of the subarea. The example of equal subareas is presented, however the choice of their size, shape and location should be an issue of a further research.

Mapping spatial distribution of the three factors (agricultural land, high fertile agricultural land and optimal soil pH) brings the conclusion that the central part of Lower Silesia is the most favourable region for agricultural use, especially in subareas where the standard deviational ellipses and centroids are nearly overlapping (subareas 7th, 10th, 12th) which means that the best soil conditions and fertile land are within all agricultural lands. These areas constitute nearly 20% of agricultural land in Lower Silesia and embraces most of the area within Silesian Lowlands. The research revealed also the regions where the distribution of the favourable conditions are located in a specific places of agricultural land (subarea 8th, 9th, 15th). That relates to the south-western part of Lower Silesia.

WIZUALIZACJA ROZKŁADU PRZESTRZENNEGO WYBRANYCH ELEMENTÓW ŚRODOWISKA PRZYRODNICZEGO ZWIĄZANYCH Z GOSPODARKĄ ROLNĄ W WOJEWÓDZTWIE DOLNOŚLĄSKIM

Streszczenie: Statystyki przestrzenne pozwalają opisać i ocenić zjawisko pod kątem jego przestrzennych charakterystyk takich jak: koncentracja, wielkość i ukierunkowanie rozproszenia, występowanie regularności lub trendów w przestrzeni. W artykule zaprezentowano adaptację metod stosowanych dla zjawisk punktowych do oceny rozkładu przestrzennego zjawisk powierzchniowych związanych z gospodarką rolną: powierzchnia użytków rolnych, powierzchnia gleb zakwalifikowanych jako dobre, powierzchnia gleb o danym odczynie. Mapy zasięgów tych zjawisk (np. mapa glebowo-rolnicza w postaci wektorowej) jako jakościowe dane wejściowe zostały przetworzone na dane ilościowe odniesione do siatki o wymiarach 1 x 1 km za pomocą algorytmu stworzonego w środowisku Model Builder.

Obszarem badań jest województwo dolnośląskie charakteryzujące się różnorodnością warunków przyrodniczych, co wpływa na zmienność przydatności rolniczej badanego terenu. Statystyki przestrzenne wyznaczone dla całego obszaru dostarczają tylko ogólnej informacji o rozkładzie przestrzennym, stąd też w pracy przeprowadzono analizy w podobszarach, co pozwoliło na zbadanie lokalnej zmienności wybranych warunków przyrodniczych. Z uwagi na rolniczy aspekt badań zaproponowano podobszary o równej powierzchni użytków rolnych, uwzględniając granice administracyjne. Rozkład przestrzenny opisują takie miary jak: środek ciężkości, odległość standardowa, elipsa odchyleń standardowych. Uwzględ-

niają one nie tylko lokalizację obiektu, ale również wartość zjawiska. Wizualizacja miar rozkładu przestrzennego na mapie dostarcza jasnej i zwykle łatwej w interpretacji informacji o strukturze przestrzennej badanego zjawiska. Prezentacja tych ilościowych charakterystyk na tle zjawiska przedstawionego inną metodą kartograficzną (np. metodą kartogramu) może wnosić dodatkowe informacje, w tym przypadku dotyczące przydatności warunków przyrodniczych dla gospodarki rolnej.

Słowa kluczowe: rozkład przestrzenny, metoda centrograficzna, środek ciężkości, odległość standardowa, elipsa odchyleń standardowych

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