

Essays on the theory of water management¹

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Abstract. Alexander Chayanov visited European countries many times but never visited Asia outside the Russian Empire and USSR; however, his visits to Russian/Soviet Turkestan (as the territory of today's Uzbekistan, Turkmenistan, Kyrgyzstan and Tajikistan was called and administered in the early 20th century) from 1915 to 1927 were reflected in several works. Before the 1917 Revolution, 28-year-old Chayanov visited Samarkand (Uzbekistan) to study irrigation and water management in the Central Asian regions. The results of this research were published as "Essays on the theory of water management", which he begun in 1915 in Samarkand and completed in 1917 in Moscow. Chayanov wanted to study water rent — the oldest and still relevant problem of Asian irrigation, already having some experience of studying the economy of European irrigation: in 1908, during his postgraduate internship in Italy, he had studied the economy of the oldest European irrigation systems in Lombardy. To theoretically generalize European and Asian irrigation, Chayanov wrote these essays as a cascade of abstract marginalist schemes, ingeniously transforming von Thünen's famous economic-mathematical model of the isolated city-state into his model of the isolated oasis-state for Turkestan — in the center of a great desert, there is an isolated oasis-society, whose entire agriculture is based on irrigation. At the center of this equally fertile and waterless vast plain, there is a single water source — property of a small number of individuals who sell water to farmers competing for it. This constructed object is analyzed through numerous, increasingly complex marginalist examples of the economy of the isolated oasis-state. The initial oasis model is further expanded to include land of varying quality and the natural cyclical functioning of the water source. Chayanov concludes his work with institutional questions about the role of water owners in national economy, social regulation of water, promotion of rational water use and trade-offs in water distribution. Chayanov wanted to test his theoretical model on empirical data from fieldwork but could not do it. A century later, today's generation of historians, sociologists, economists and anthropologists studying irrigation in arid regions of the globe may find these abstract essays useful.

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I. Introduction

The current radical change in land relations sets the most difficult tasks of state building for the organized public consciousness of the Russian people. The diversity of economic structures in various regions of our fatherland complicates this work by making us take local peculiarities into account.

Some regions of Asian Russia, in which most agricultural crops require irrigated land, take a special position in this regard. Our limited knowledge of the conditions of irrigated agriculture and water management hinders our creative work on the agrarian development of these irrigated regions.

There is insufficient study of such fundamental issues of this type of national-economic life as *water rent*, *coexistence of water rent and land rent*, *irrigation tariffs*, and some other issues related to water management. The lack of Russian works on these issues allows us to publish unfinished studies of water management, which are mainly based on materials collected by the author in Lombardy in 1908 and in Turkestan in 1915.

II. Water rent

What is water rent? Is it independent and separate from land rent?

In the valleys of our Turkestan, we see vast, economically boundless expanses of land, fertile in soil composition but barren without artificial irrigation. When studying the economic life of these valleys, we see that water — *the right to a certain amount of water* — has a price beyond the costs of building and maintaining irrigation structures. In some districts of Fergana, the right to water is even an *object of property rights*, separate from land ownership, for those who do not have ownership rights to water.

On the other hand, we cannot deny the existence of land rent — the price of land regardless of irrigation costs. In other words, there is coexistence of two types of rent, and before beginning our analysis of the fundamentals of water management, it is necessary to clearly understand the nature of *water rent*, the grounds for separating it from land rent, and the economic consequences of its very existence.

Irrigation water, which is limited (marginal) in quantity and thus gives rise to the phenomenon of water rent, is significantly different in nature from land as a source of land rent. Land plots different in fertility differ greatly in their spatial location and market positions;

the worst plot in terms of a given scale of production as the marginal plot determining the size of differential rent is also fixed in space.

In contrast to the described properties of land as a source of rent, water that irrigates fields is not fixed in space, its supply can be transferred to any location, and each water unit is not different from any other unit (there are some agricultural differences in varying water temperatures due to the distance of diversion canals from the main waterway and different levels of siltation; however, in a theoretical analysis of water rent, these differences can be ignored, since none of them can be defined as the marginal worst). These differences cannot but be reflected in water rent and influence its theory in a peculiar way.

In our analysis of the nature of water rent, we can proceed from two positions:

1. Food prices are entirely determined by production on land that does not require irrigation; therefore, these are given values in relation to irrigated farming.
2. Food prices and the size of water rent are conjugate variables and are determined by the equilibrium of economic factors.

The second position is of exceptional theoretical interest, and we could conduct its theoretical analysis by studying a hypothetical isolated state — an oasis — with all its agriculture based on irrigated land. However, the complexity of the problem makes us begin with a simpler task, especially since in practice the price of agricultural products is determined by non-irrigated farming of our Turkestan, which is the main object of our research.

Let us consider the simplest case — a plain of infinite fertility and completely devoid of water, land unsuitable for agricultural production without irrigation. The only limited water source is owned by a small number of non-farmers who sell water to farmers competing for it. For simplicity of analysis, let us assume that water can be supplied to any point on this plain at equal costs and that the farm-gate prices of agricultural products are the same throughout the plain.

Let us further assume that there is only one crop grown on irrigated fields (A), and its yields are determined entirely by the amount of irrigation water and are subject to the law of diminishing returns. The figure below shows the relationship between irrigation intensity (x-axis) and yields (line AB). The curve shows that at a given optimal level of irrigation, yields reach a maximum and then decline due to difficulties with aeration or soil waterlogging.

To understand the nature of water rent, first we should answer the question of the level of maintained field irrigation as determined by economic considerations and of how much the farmer can and will pay the owner of water for its use. If we assume that the farm under study is run on capitalist principles, i.e., aims at maximizing net profit, then the level of irrigation depends on the degree at which the difference between gross income and costs is greatest. If water is sup-

plied to the farm free of charge, and the costs of cultivation, including interest on capital (line CD), are the same for all levels of irrigation and yields, i.e., gross income (line AB), then it is easy to see in Figure 2 that the highest net return (xy) will be achieved with irrigation corresponding to the maximum yield.

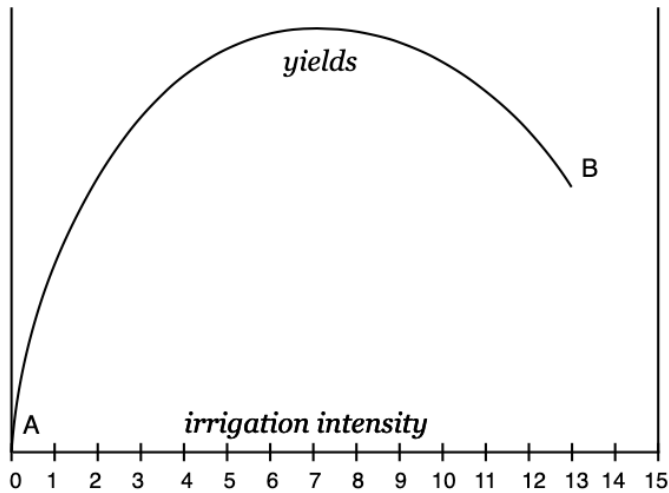


Fig. 1. Dependence of yields on irrigation

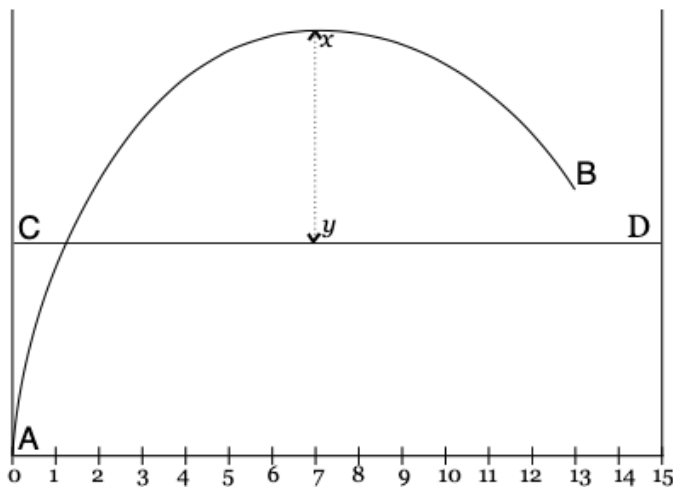


Fig. 2. Gross income, fixed costs, and net return

The situation is different if farmers pay for each unit of irrigation water, as can be seen in Figure 3: line CD indicates

the cost of the crop at a price of 1 ruble per cubic meter of water. In this case, the maximum difference between gross income and costs (ZW) corresponds not to the technically optimal irrigation but to a lower irrigation level which turns out to be more cost-effective (6 cubic meters instead of the technical optimum of 7 cubic meters).

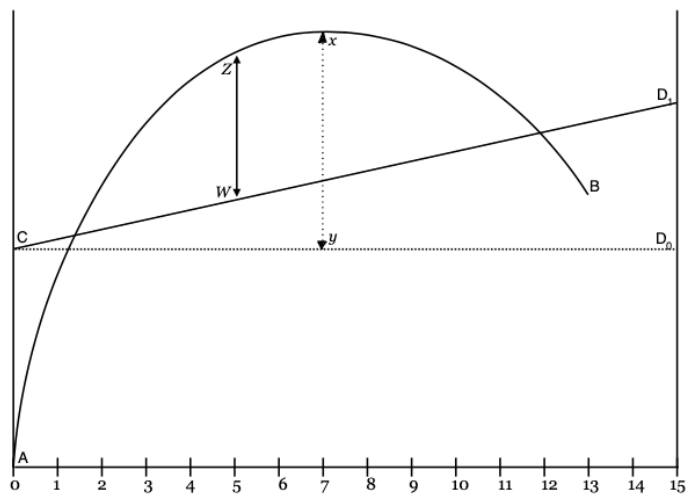


Fig. 3. Gross income and net return when paying for water

As can be seen in Figure 4, the higher the water price, the more economically rational the lower yield, until we finally reach a water price at which any agricultural activity becomes economically impossible. Thus, paying 2 rubles per cubic meter reduces cost-effective irrigation to 5 cubic meters, 3 rubles — to 4.3 cubic meters, and 4 rubles — to 3.5 cubic meters, which allows only for farming without both profit and loss; any higher water price leads to losses for the agricultural enterprise.

The question is what fee water owners will charge farmers for water use, and what the corresponding level of irrigation and the total area of cultivated land will be. With free water use, farmers would undoubtedly achieve the technical optimum, irrigating an area equal to the quotient of total power of the supply source divided by irrigation of one desiatina, and would pocket the difference between gross income and production costs (including interest on capital). This unearned income would create competition, and many farmers would offer to pay 1 ruble per cubic meter and organize their farms outside the zone of technically optimal irrigation. The price of 1 ruble per cubic meter would reduce irrigation of one desiatina, area of cultivated land would increase, and

farmers, despite reduced rental income, would still receive significant income. Undoubtedly, this situation would increase competition, and there would be farmers willing to pay 2 and then 3 rubles for water and organize farms on new, previously unirrigated lands.

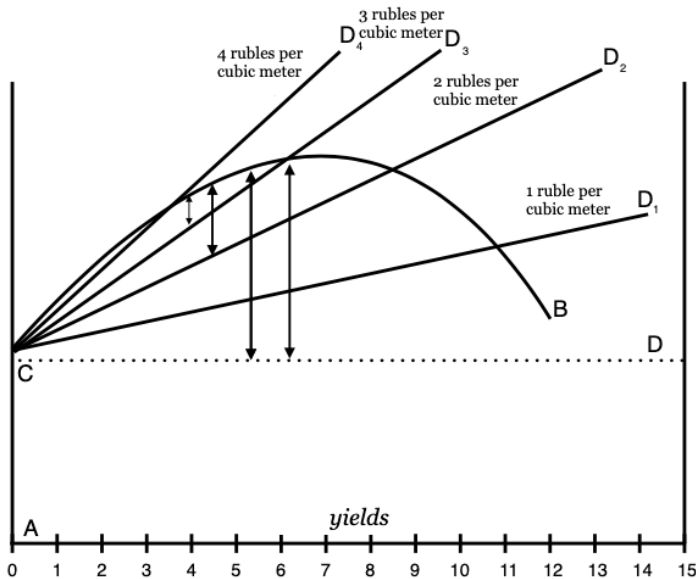


Fig. 4. Net return at different water prices

This competition, rise in water prices and expansion of crop areas due to reduction of irrigation per unit of land would continue as long as the water owner receives unearned rental income; finally, he would fatally raise price per cubic meter to 4 rubles, at which farmers would receive only wages and interest on capital, while the water owner all other unearned income. This would eliminate any further competition and determine both the level of irrigation and the area cultivated, since any further increase in water price would make any capitalist-type farming on irrigated lands impossible.

Figure 5 shows how the area of irrigated land gradually expands under competition: money received by water owners is rent for water the volume of which is limited. Provided boundless fertile land and limited volume of water that can be supplied to any point, there are no conditions for any other rent, including land rent, than water rent. Thus, water rent in this case determines both size of cultivated land and intensity of irrigation.

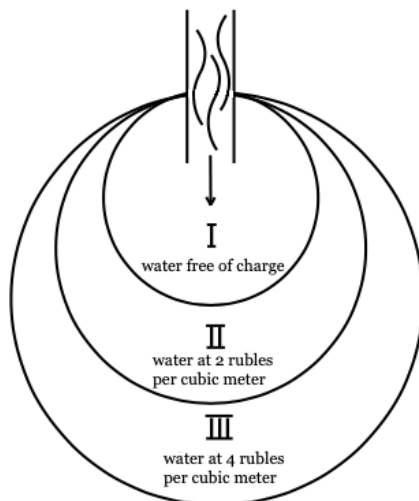


Fig. 5. Expansion of irrigated land under competition

Let us clarify whether this area, this irrigation level and consequently yields correspond to the national-economic interests. Obviously, from a national-economic perspective, the optimal size of cultivated land and the corresponding optimal irrigation ensure maximum yields with a given water source. It is easy to prove that this desired irrigation level may not be the level providing maximum yield per desiatina. Indeed, total yield from the entire area irrigated by our source (line PRS in Figure 6) is the product of sown area (line AB) and yield per unit (line RLM).

Of these factors, one — sown area — constantly grows as cultivated land expands, while the other — yield — is initially low due to flooding of fields, then rapidly grows, reaches a maximum, and begins to slowly fall. Accordingly, the product of these factors, as can be seen in Figure 6 (x-axis shows irrigated area), is initially zero, then rapidly increases, and, having reached a maximum at a certain point, begins to decrease just as quickly. Irrigation corresponding to this maximum seems to be the most desirable in terms of national-economic interests, and, as can be seen in our figures, this irrigation may be neither the one that ensures the highest yield per unit nor the one that ensures the highest rent for water owners. Therefore, in the conditions that we consider initial for the state economic policy, it is necessary to limit irrigated area, volume of irrigation and consequently rent according to the maximum extraction of agricultural products from the source under study.

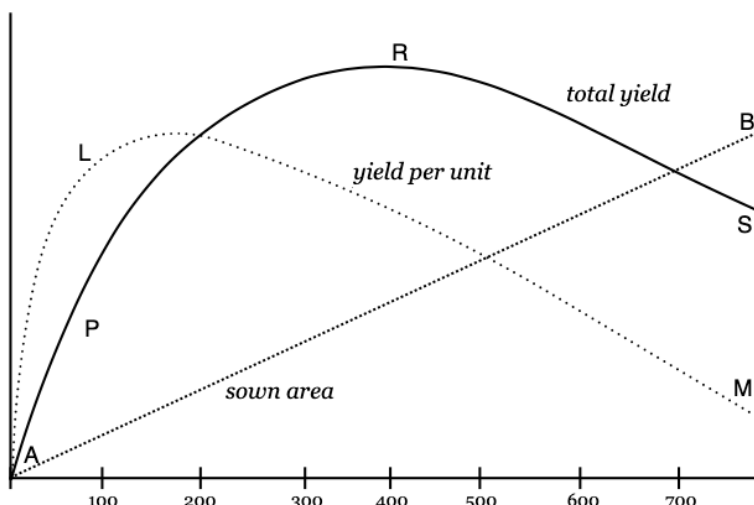


Fig. 6. Yields and sown area for different sizes of irrigated land

III. Cases of coexistence of water rent and land rent

In the previous chapter, we considered the origin and nature of water rent in the most simplified, schematic formulation. Let us now make initial conditions more difficult and assume, all other things being equal, that irrigated land is heterogeneous in quality and divided into four categories: very good (I), good (II), average (III), and low-fertility (IV). The first three categories are limited and even with technically optimal irrigation leave a significant amount of water for irrigating comparatively low-fertility lands of the fourth category.

Due to different sizes of land, the effect of irrigation on each category will be different, which can be seen in Figure 7 with four curves of gross income per desiatina as depending on intensity of irrigation.

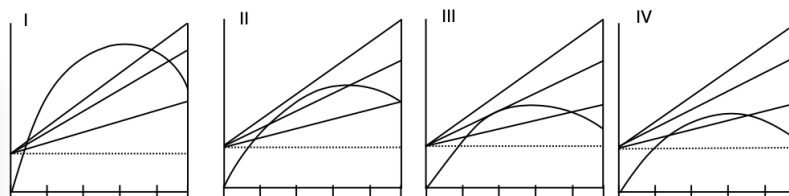


Fig. 7. Irrigation effect, gross income, costs, and net return on lands of different quality

These curves show different levels of optimal irrigation corresponding to maximum yields for each land category; net yield per desiatina will also vary, provided equal production costs. If, like in the previous chapter, we gradually increase the price of water from 1 ruble to 2, then to 3 and so on, the fourth category of land will reach the point of being unable to withstand further increases in water charges much faster than other categories.

It is easy to prove that, under our assumptions, this marginal water price, at which cultivation of the fourth-category land is still possible without loss albeit without profit, will be the determining factor in water rent for the entire oasis. If landowners increase water charge, the fourth-category land will cease to be cultivated, and, according to our assumption, there will be a lot of excess water unnecessary for lands of the first three categories. Water owners will compete, and water prices will inevitably fall to a level at which cultivation of the fourth-category land will become economically reasonable again. Therefore, the level of water rent and payments for it will be in line with the marginal charge for farmers working on the fourth-category land; while farmers working on the best lands, even after deducting production costs, interest on capital and water rent from gross income, will still have some net profit, and the more fertile the cultivated land, the greater the net profit (Figure 7).

This remaining net income represents ordinary differential land rent, which in this case coexists with water rent. To emphasize the relationship between these two types of rent as clearly as possible, let us make some changes in our initial conditions and assume that the volume of our irrigation source significantly decreased, and it is sufficient to provide only for the first two categories of land and part of the third category.

As can be seen in Figure 8, water shortage will lead to fierce competition between owners of the third-category land, resulting in rising water prices, and all farms on the fourth-category land will lose any opportunity to continue cultivation and will cease to exist. Water prices will rise and irrigation will decline until land rent reaches a level at which owners of the third-category land receive neither profit nor loss beyond covering costs and interest on capital. It goes without saying that the third-category land will no longer provide rent, while rent for the first- and second-category land will correspond to new water rent and will fall significantly. Thus, *a decrease in the volume of water source increases water rent and decreases land rent.*

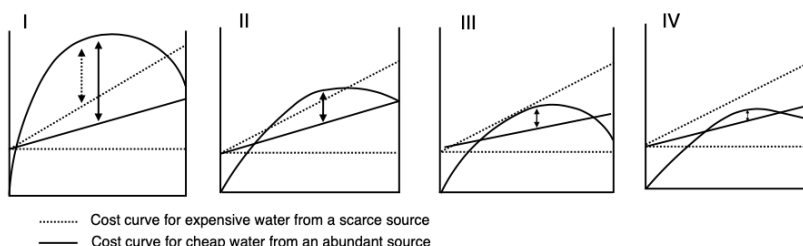


Fig. 8. Effect of increasing and decreasing water source

Let us now assume that the water source increases so much that it is sufficient not only to satisfy the demands of owners of the first three categories of land but also to bring the fourth-category land, i.e., all the land in the country, into cultivation. In such conditions, the old, originally set price for water can be kept only if there is just enough water to irrigate all land of the fourth category to the level of initial irrigation; if there is more water, competition between owners is inevitable, and they will have to lower price to distribute all water among farmers. With a decrease in water price, maximum net return of farms on all four categories of land will correspond not to the old irrigation but to a different, more intensive one. Accordingly, the overall demand for water will increase, and all excess water will be used by farms. This decrease in land rent, as can be seen in Figure 8, leads to an increase in the remainder of gross income after subtracting production costs, interest on capital and water charges, i.e., to an increase in land rent. It should also be noted that land rent is also introduced for the fourth-category land.

As the water source increases, water owners, unless they organize a syndicate, will be forced to reduce prices of water to distribute it among farmers-consumers, until finally the demand for water is completely satisfied, irrigation is brought to the technical optimum corresponding to the highest yield per unit, and any further use of water for irrigation is devoid of economic sense. In these conditions, water rent will be zero, and land rent will reach its maximum at the current level of production.

What we have just presented provides a clear understanding of the nature of land rent and its fundamental laws. To bring our model closer to reality, we should take into account the increasing costs of water (depending on the distance of irrigated field from the water source) and the varying farm-gate prices (depending on the distance of the farm from the market). However, taking these factors into account will not change the results of our analysis, since theoretically worse conditions of land plots can be considered as the already assumed decline in soil fertility.

ТЕОРИЯ

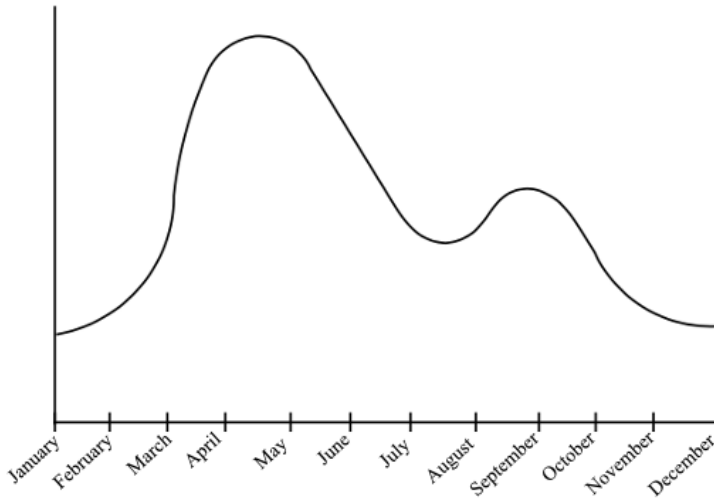
In one of the previous chapters, we saw that complete freedom of private economic interests can lead to such forms of water use that, while ensuring maximum water rent for water owners, do not ensure full agricultural productivity of the national economy. In this case, the intervention of the organized public consciousness through some regulation of water use can orient water management towards greater alignment with national-economic interests. State intervention in the organization of land use will be even more necessary as we move from theoretical models to practice.

In traditional farming, land is always part of farms and no one except the owner works on it; in irrigated farming, the life-giving principle — water — is transferred from its source to irrigated fields through other farmers' lands, which is why without public regulation of water use it can be repeatedly taken along its route of transfer, and its final distribution can easily lead to numerous violations of both private and national economic interests. For example, increased water intake from upper reaches of the river by irrigation systems can completely destroy traditional agriculture in its middle and lower reaches; increased water intake by thickets of alchemilla deprives cotton fields of water, and so on. Therefore, while in traditional dry agriculture the organized public consciousness can limit itself to judicial protection of land rights and land borders, in irrigated agriculture it should intervene in water distribution, take control of water supply and develop a more or less complex water management.

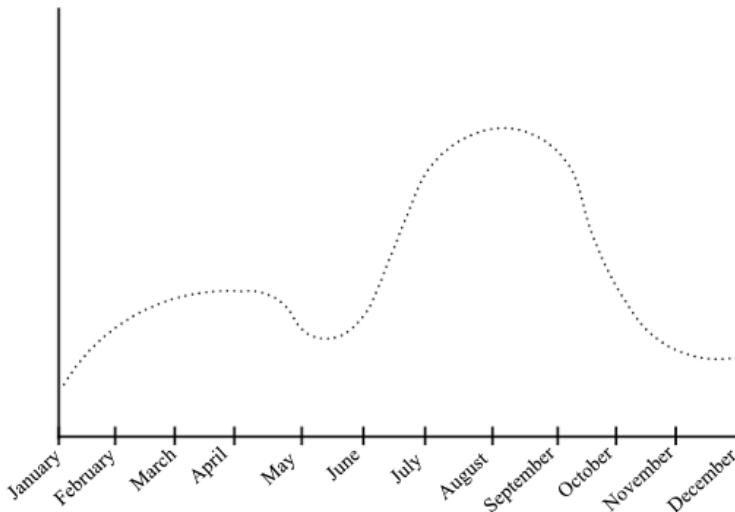
In our Turkestan, such public regulation was established several centuries ago; customs, khan's charters and sometimes even armed force guarantee the rights of each village to water, and numerous *aryk-aksakals* and *mirabs* monitor the observance of these rights. However, in its current form, this public regulation is limited to protecting once-and-for-all established private rights to water, while interests of the national economy demand a much more flexible use of state intervention and water distribution rights, primarily in the interests of maximizing national economic productivity rather than in the interests of individuals who, for whatever reason, once seized legal rights to water.

Such *active* water management is extremely complex, and its foundations are extremely poorly studied. A few explanations will be enough to understand the complexity of our task. Any natural water source that serves as the basis for irrigation is not a continuous and uniform flow, its power depends on its nature — sometimes its flow increases, sometimes decreases. The power of this flow, measured at different times of the year by the amount of water flowing through a waterway per unit of time, is called the *water flow regime* and provides us with a variety of curves depending on the nature of the water source.

Let us assume that the water source that serves as the basis for irrigation has the water flow regime as shown in the figure below.

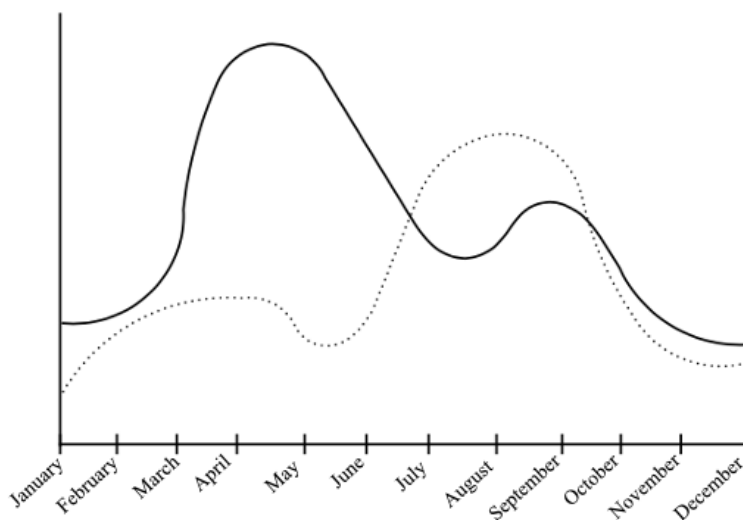


The specified water flow regime does not always coincide with the required irrigation regime. The timing of irrigation and the amount of water used are determined by the needs of crops: rice, cotton, grapes, alfalfa, cereals and all other crops have their own special irrigation regimes. Since different crops are grown in irrigated fields, the final irrigation regime is determined by the sum of the needs of individual crops. It goes without saying that this final irrigation regime depends on crop rotation and crop composition. The figure below provides an overview of one irrigation regime.



Obviously, the irrigation regime will not always coincide with the water flow regime: during periods of weakening water flow there will be

an acute need for water; on the contrary, during the flood period, there will be no need for water. The figure below indicates such a mismatch.



We see that the spring peak in river flow is not suitable for irrigation and is useless for agricultural crops, while during the summer peak in irrigation there are water shortages that limit sown area. This contradiction can be resolved in two ways:

1. *Engineering* — creating special reservoirs to hold spring waters for low-water periods.
2. *Agronomical* — developing such crop rotations and combinations that better match the irrigation regime to the water flow regime.

Undoubtedly, the organized public consciousness should use both ways, and it really does. Moreover, the second approach — matching the irrigation regime to the water flow regime by changing crop rotation — in most cases is spontaneously mastered through the slow, centuries-long evolution of agriculture, and only in the last decade has social agronomy attempted to subordinate it to the guidance of the organized public consciousness. Unlike social-agronomic work in dry farming, when agronomists use persuasion and verbal pressure, in irrigated farming we can reinforce our propaganda by regulating water use — increasing water supply for certain crops and their combinations and stopping water supply for harmful crops.

This power comes with enormous responsibility, and those who lead active water policy should have a clear and precise understanding of some principles that give their work national significance. *First*, we should not get carried away with technically efficient water use; we should not necessarily strive for an ideal match of the irrigation regime with the water flow regime, when they completely coincide. It

is likely that, having achieved this technical ideal, we will still have some low-profit or even unprofitable crops in our rotation, and the overall profit from using the flow will not be the maximum possible. It is also likely that the most cost-effective crop composition, with maximum yields under irrigation, will correspond to an irrigation regime curve completely different from the water flow regime, therefore leaving a significant amount of unused water. Nevertheless, this irrigation regime will still be the most profitable.

Second, when creating new irrigation systems and populating the corresponding territories, we should take into account that the farming system with the greatest benefit from the water source may require exceptional amounts of labor and capital but ensure low returns per unit of labor and material costs. Here, the national-economic interest will put the purely economic interest in very difficult conditions, and irrigation organizers will have to modify the designed system to find an acceptable compromise between both interests.

Third, one should remember that the irrigation stream often flows through diverse climate and soil zones, and those who plan active water management face a very difficult task of organizing it for each zone without losing sight of the economic impact of the entire water flow. It is likely that many zones will have to refuse the most beneficial irrigation regimes, since the needed cubic meters would be used with much greater effect in other zones.

The system of agriculture and water use based on these principles can be implemented by simple quantitative regulation of water use. However, this method is extremely rough and often burdensome for farmers and, on the other hand, fails to solve many problems associated with active water use. Therefore, this method should be supplemented and partially replaced by various water pricing systems.

V. Irrigation tariffs

Under free competition and inclusion of all irrigation water in private trade, independent of land turnover, water prices would undoubtedly be set at the level of water rent analyzed in the first chapters. However, with rare exceptions, there is no free private trade in irrigation, and in most cases, even when the landowner receives water for a fee, the legal entity providing water is in a monopoly position. There are frequent cases of free of charge water supply to irrigated fields, when farmers pay not water rent but only costs of maintaining and operating the irrigation system. This is the dominant situation for our Turkestan, since there, according to Sharia, water is a common property, only land is subject to trade, water rent is included in land rent, and water is considered an integral and legally secured part of a given land plot. Moreover, the typical water rationing for a given land plot is based not on the number of cubic meters or power

of the water flow in cubic seconds over a given period but on shares of the irrigating flow (a certain village has the right to $\frac{2}{5}$ of water, another village — to $\frac{1}{5}$).

In the village, households are divided into groups that receive shares of the village flow, groups on a waiting list, and so on. So, ideally, each desiatina of the irrigation system, say of 6,374 desiatinas, has the right to $\frac{1}{6,374}$ of the water source. In reality, due to seizures, purchases and so on, rights confirmed by old charters and the like are far from equal; sometimes the division of water between groups of farms depends on the size of holes in the old wooden divider. According to water shares, costs of maintaining and repairing this irrigation system with all its aryk-aksakals, mirabs and other characters are distributed among farms, often in kind.

This system leaves water rent to landowners and is the most conservative form of public water management which refuses any active policy and passively supports the once-and-for-all established land-water relations. This system would be equally conservative if the self-governing water community is replaced by some monopolist collecting all or part of water rent from water users. Conservatism disappears when the water management body begins to redistribute water according not to shares of the flow per desiatina but to the needs of crops, farms, and the common national-economic interest. To support crops beneficial to the state, this water management body can increase water supplies to farms cultivating them and reduce water tariffs, while, to get rid of crops harmful to the national economy, this body can reduce water supplies and increase water charges. The latter measure is often entirely sufficient to achieve results without forced rationing.

Such a system of active water management requires great awareness, sufficient caution and at the same time decisiveness and continuous monitoring. Tariffs should follow price changes for both products and means of production. Perhaps it is precisely the complexity of this system and the constant mobilization of public and state forces it requires, which is beyond the capacity of existing social organisms, that have prevented this system of active water management from being fully implemented.

As a rule, existing tariffs and water use regulations take a middle position between the two described types. We often have a simple, uniform payment per cubic meter; sometimes, in water-rich systems increased consumption and irrigation of new areas are encouraged by preferential tariffs. On the contrary, in water-poor systems any excess consumption beyond the standard rate is additionally charged; we have even heard of systems in which the estimated amount of water remaining after satisfying the minimum needs of all participants is auctioned off by irrigation companies to their clients.

In general, the theory of water tariffs, like the theory of water management, is in its infancy.

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Аннотация. Александр Чаянов неоднократно посещал европейские страны, но никогда не бывал в зарубежной Азии — за пределами Российской империи и СССР. Тем не менее посещение российского/советского Туркестана (так называлась и административно управлялась в начале XX века территория нынешних Узбекистана, Туркменистана, Киргизии и Таджикистана) в 1915–1927 годы было отражено в ряде его работ. Перед революцией 1917 года 28-летний Чаянов впервые оказался в Самарканде (Узбекистан), где занимался изучением ирригации и водного хозяйства центральноазиатских регионов. Результатом его исследовательской деятельности стала публикуемая работа «Очерки по теории водного хозяйства», начатая в 1915 году в Самарканде и завершенная в 1917 году в Москве. Чаянов поставил задачу изучить водную ренту — древнейшую и до сих пор актуальную проблему азиатской ирригации, уже имея некоторый опыт исследования экономики европейской ирригации: еще в 1908 году во время аспирантской стажировки в Италии он изучал экономику старейших европейских ирригационных систем в Ломбардии. Стремясь теоретически обобщить европейский и азиатский опыт ирригации, Чаянов представил «Очерки по теории водного хозяйства» как каскад абстрактных маржиналистских схем, оригинально трансформируя знаменитую экономико-математическую модель изолированного города-государства фон Тюнена в модель изолированного оазиса-государства на фоне Туркестана, где в центре великой пустыни располагается изолированное общество-оазис, все земледелие которого базируется на орошаемых землях. В центре этой равно плодородной и равно лишенной воды обширной равнины находится единственный водный источник — собственность небольшого числа лиц, продающих воду конкурирующим за нее земледельцам. Этот сконструированный объект анализируется через многочисленные постепенно усложняющиеся маржиналистские примеры функционирования экономики изолированного оазиса-государства. В изначально предложенную модель оазиса вводится условие земель разного качества, а затем природной цикличности функционирования водного источника. В конце работы Чаянов ставит институциональные вопросы о роли владельца воды в народном хозяйстве, общественном регулировании воды, пропаганде рационального водопользования и компромиссе в распределении воды. Чаянов намеревался проверить свою теоретическую модель конкретными эмпирическими материалами полевых исследований, но не успел это сделать. Век спустя нынешнему поколению историков, социологов, экономистов и антропологов, изучающих проблемы ирригации в засушливых регионах земного шара, возможно, будет полезен этот чаяновский абстрактный этюд.

Ключевые слова: ирригация, оазис, водная рента, водное хозяйство, землепользование, засушливое земледелие, изолированное государство

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