International Journal of Mechanical Engineering

CHANGES OF SOLAR RADIATION IN THE IRRIGATED TERRITORIES OF UZBEKISTAN

Gulman Kh. Kholbaev

National university of Uzbekistan,

Uzbekistan

Khamroqul T. Egamberdiev

Hydrometeorological Research Institute,

Uzbekistan

Feruza Aripdjanova

Hydrometeorological Research Institute,

Uzbekistan

Abstract: The article analyzes the change in the amount of direct radiation and scattered radiation perpendicular to the surface during the growing season of winter wheat grown in irrigated areas of the Republic of Uzbekistan, the amount of photosynthetically active radiation. In moderately cloudy conditions, the sum of direct (S`, MDj/m^2) solar radiation falling horizontally is observed in industrial centers with a low monthly sum. The monthly sum of "D" of the scattered radiation depends on astronomical factors (the height of the Sun above the horizon and the length of the day), the clarity of the atmosphere, and the albedo of the earth's surface and clouds. less than 50% of the number of open days in irrigated areas occurs in November-April. The main minimum was observed in December. The total radiation of PAR and the distribution of its constituents are related to latitude.

Keywords: Sun, radiation, energy, scattered, photosynthetic active radiation, agriculture, vegetation.

INTRODUCTION

Solar radiation is the main source of the Earth's heat balance, water circulation in the body, creating an autotrophic chain of the biosphere and converting it into organic matter. This, in turn, allows organisms to form an environment that satisfies their life activities.

Sunlight reaching the upper limit of the Earth's atmosphere is 1,367 kJ/m^2 v per second. This magnitude is called the solar constant. Solar radiation contains a wide range of electromagnetic radiation. In terms of energy, solar radiation is almost (99%) in the range of l = 300–4000 nm. Ultraviolet light shorter than 290 nm is lethal to living organisms. It is absorbed in the ozone layer of the troposphere and does not reach the Earth's surface.

Radiation reaching the soil or vegetation is divided into shortwave (l = 300-4000 nm) and longwave (l> 4000 nm) radiation. More short-wave radiation is important for the vital activity of organisms, which in turn is conditional ultraviolet (l <400 nm), visible (l = 400-760 nm) and info-red (l = 760-4000 nm) radiation. Under light energy in this spectral range, important photobiological processes take place in living organisms (mainly plants). Within the boundaries of this section, the field of photosynthetically active radiation (l = 380-710 nm), which solves the regulator-energy value in plant life, absorbs the light energy absorbed by leaf pigments (Chirkov Yu.I. 1988).

In the new conditions of state independence and on the path of independent economic reform and the transition to market conditions, the Republic faces difficult tasks such as food security, fuel and energy resources, strengthening economic and political sovereignty. For this reason, the efficient use of solar energy in agriculture is relevant. The solution to this important direction is to optimize the correct placement of solar energy in agriculture by regions, taking into account the energy demand of plants.

Directly in abroad, researchs about Scattered solar radiation (by Sivkov S.I. 1968, Power H.C. 2003, Mingzhong Xiao and ets. 2020, Olseth J.A.&Skartveit A. 2001), The duration of sunlight exposure (by Stanhill G., Cohen S. 2005, Bannani F.Kand ets. 2006), daily and for hours (by Codato G. And ets. 2008), The radiation mode (by Pivovarova Z.I. 1959, Chizhevskaya M.P. 1962, Shulgin A.M. 1978, Zhengfang Wu, end ets.. 2012, Gorbarenko E.V. 2020,) The effect of radiation mode to air temperature (by Zhengfang Wu, end ets. 2012), Changes in the vegetation period (by Hua Zhang, end ets. 2013), Photosynthetic active radiation (by Ustenko G.P. 1963, Nichiporovich A.A. 1966, Tsubo M.& Walker S. 2005, Yang ZL, Zhang TB, Yi GH, et al. 2021), in Uzbekistan, The usage of solar energy by Alekseeva V.V. and Nefedovoy L.V. (1992), Lukashevich V.S. (1985), Tulko Yu.M.

(1983), Axmedova R.V. (1983), Korenova V.E. and others. (1982), Bayramova R.B. and others. (1993), Dyurana G. (1992) had been done. In addition, On the possibilities of using solar energy due to the nature of the region by Egamberdiev Kh.T. 1995, Egamberdiev Kh.T., Petrov Yu.V. (2018), Applied solar, (1986). On cotton, rice plants by Babushkin L.N., Kogay N.A. (1964), Abdullaev Kh.M., Kratenko A.Yu. (2008) researches had been done. Solar radiation atlas (Atlas of the Uzbek SSR. 1982, 1985, Scientific and Applied Reference Book on the Climate of the USSR. 1989) was developed. The changes in air temperature during the growing season of winter wheat grown in irrigated areas of the regions of the Republic of Uzbekistan was analyzed by Kholbaev G.Kh. end ets. 2020, Kholbaev G.Kh., Abdullaev A.K., Egamberdiev Kh.T. 2020, Kholbaev G.Kh., Egamberdiev Kh. T. 2021). However, the variation of solar radiation, photosynthetically active radiation during the growing season of winter wheat plants grown in irrigated areas is almost not studied.

The main purpose of the study is to determine the number of direct sun, scattered radiation, number of open and cloudy days, duration of sunlight, changes in the values of photosynthetically active radiation by months, spatial-temporal distribution of solar radiation during the growing season of winter wheat grown in irrigated areas of Uzbekistan is to develop methodological and practical recommendations on

OBJECTIVES AND METHODS OF RESEARCH

The object of the study was the data of actinometric observations carried out at actinometric stations located in irrigated areas of Uzbekistan, which were primary data based on a single instruction (Guidance, 2009), which were used in the sources (Abdullayev A.Q., end ets. 2008, Ulanova E.S. 1968) and methods recommended by the World Meteorological Organization (WMO, 2017)
In the study, the actinometric stations (Taxiatash (76 m), Tamdi (236), Tashkent (477 m), Ferghana (578 m), Samarkand (726 m), Termez (308 m)) which conduct the study of solar radiation generators (the sum of direct (S`) and scattered (D) (MDj/m^2) solar radiation occurring horizontally in moderately cloudy conditions) located in irrigated areas of Uzbekistan.

THE RESULTS OF THE RESEARCH AND THEIR DISCUSSIONS.

It is known that winter wheat is sown in September-October. Therefore, first of all, based on the data of actinometric observations at actinometric stations located in the regions, the change of the sum of solar radiation straight (S`) and scattered (D) (MDj/m^2) occurring in months during the growing season in moderate cloudiness (Figure 1-2).

1) The sum of direct (S`, MDj/m^2) solar radiation incident horizontally on average cloud cover

As can be seen from Figure 1, the minimum value during the growing season of winter wheat (IX-VI) is from 60 MDj/m^2 (Fergana) to 127 MDj/m^2 (Termez) in December, and the maximum value is from 555 MDj/m^2 (Fergana) in June. 652 MDj/m^2 (Tomdi) range.

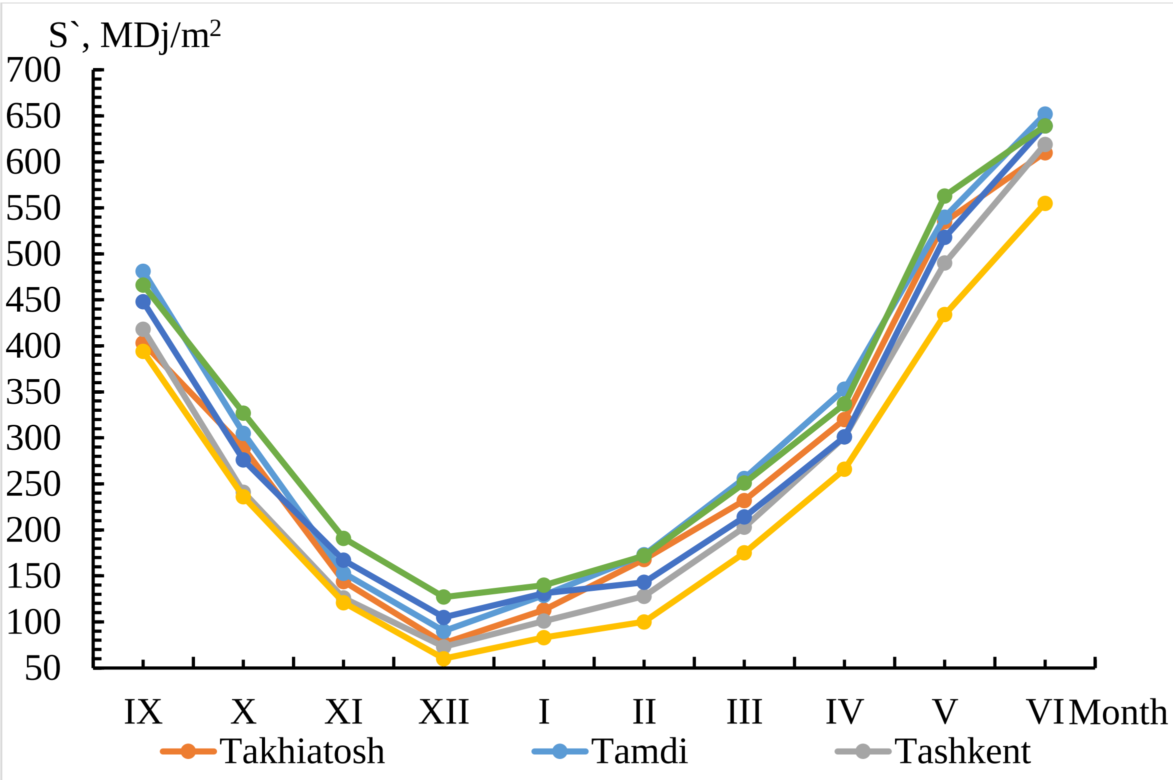

Figure 1. The sum of direct (S`, MDj/m^2) solar radiation incident horizontally under moderate cloud cover

The low monthly sum of ‘S’ is observed in industrial centers.

In general, the minimum value of horizontally incident solar radiation was observed in December, and the maximum value in June.

2) The sum of solar radiation scattered (D, MDj/m²) under moderate cloud conditions

In real conditions, the sum of scattered solar radiation describes the maximum incidence of radiation on a horizontal surface.

The monthly sum of ‘D’ depends on astronomical factors (altitude of the Sun above the horizon and the length of the day), the clarity of the atmosphere, and the albedo of the earth’s surface and clouds.

The sum of solar radiation scattered under moderate cloud conditions is characterized by the following characteristics (Figure 1).

As can be seen from Figure 2, the minimum value of “D” at the analyzed stations is 92 MDj/m² (Taxiotosh) - 111 MDj/m² (Termez) in December, and the maximum value is 248 MDj/m² (Tomdi) - 280 MDj/m² in May. (Termez) were observed in the interval.

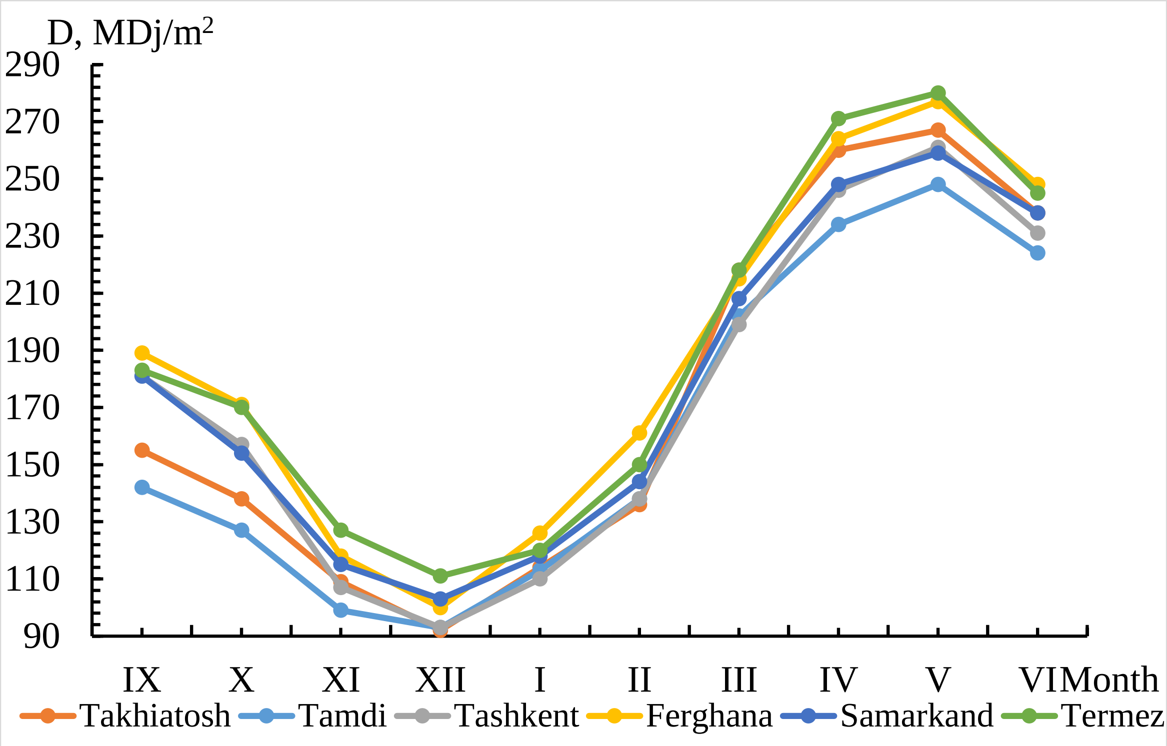

Figure 2. Scattered in moderate cloud conditions (D, MDj/m²) the sum of solar radiation

It can be seen that the distribution of the monthly value of the sum of scattered radiation is related to the atmospheric cloudiness and clarity of the regions.

Clouds have melted and become more important in the south of the republic and in the Fergana Valley due to the high turbidity of the atmosphere. In general, for Central Asia, the sum of scattered solar radiation under moderate cloud conditions differs little from the sum of radiation when the air is open.

3) The amount of clear and cloudy days

The number of open and cloudy days allows us to assess the efficient use of solar energy in Uzbekistan.

The method developed in HRI was used to calculate the number of open and cloudy days [62]. Such days are considered to be open - the relative periodicity of solar radiation is increased by 80%, cloudy - while the relative periodicity of solar radiation is less than 20%. The relative periodicity of solar radiation is determined by geligraphic records, in which case the data obtained on the amount of clear and cloudy days should be considered more objective than the results of climatic processing of cloud cover.

During the growing season of winter wheat grown in irrigated areas, more than 50% of the total number of open days was observed in September-October and May-June in the northern (Takhiatash), southern (Termez) and central (Samarkand) regions of Uzbekistan. A little less in the Fergana Valley. This is due to the local location feature of the station (Table 1).

In general, less than 50% of the number of open days in irrigated areas occurs in November-April. The main minimum was observed in December.

The distribution of the number of cloudy days by month is inversely proportional to the number of clear days (Table 2). The maximum number of cloudy days was in December-January. The second, weakest maximum - in February, the maximum - in March.

The monthly variation of open and cloudy days analyzed above is fully consistent with the nature of cloudiness and precipitation distribution in Central Asia, which in turn is characterized by the seasonal location of planetary upper frontal zones in temperate latitudes.

Table 1

At actinometric stations of Uzbekistan amount of open days,%

Station	Month									
	IX	**X**	**XI**	**XII**	**I**	**II**	**III**	**IV**	**V**	**VI**
Takhiotash	81	59	39	23	25	32	29	33	53	70
Tamdi	76	50	41	24	28	32	28	28	44	66
Tashkent	75	52	33	22	28	24	25	29	46	71
Fergana	71	48	30	15	19	16	20	26	40	56
Samarkand	82	54	43	28	34	24	20	29	55	80
Termez	85	65	49	35	30	30	29	36	61	85
Max	**85**	**65**	**49**	**35**	**34**	**32**	**29**	**36**	**61**	**85**
Min	**71**	**48**	**30**	**15**	**19**	**16**	**20**	**26**	**40**	**56**
Average	**78**	**54**	**39**	**24**	**27**	**26**	**25**	**30**	**50**	**71**

Table 2

At actinometric stations of Uzbekistan the amount of cloudy days

Station	Month									
	IX	**X**	**XI**	**XII**	**I**	**II**	**III**	**IV**	**V**	**VI**
Takhiotash	0,5	2,5	7,3	13,9	10,5	7,4	8,5	5,7	1,6	0,3
Tamdi	0,5	2,8	7,9	14,4	10,4	8,0	8,8	5,3	2,1	0,6
Tashkent	0,7	3,9	8,9	13,6	12,1	9,4	10,4	7,9	2,4	0,4
Fergana	0,9	4,1	8,6	15,5	12,4	11,3	10,2	6,7	3,5	1,1
Samarkand	0,7	3,4	6,7	10,9	10,9	9,6	9,9	6,1	2,1	0,3
Termez	0,4	1,9	4,9	9,6	10,4	8,2	8,7	4,8	1,2	0,4
Max	**0,9**	**4,1**	**8,9**	**15,5**	**12,4**	**11,3**	**10,4**	**7,9**	**3,5**	**1,1**
Min	**0,4**	**1,9**	**4,9**	**9,6**	**10,4**	**7,4**	**8,5**	**4,8**	**1,2**	**0,3**
Average	**0,6**	**3,1**	**7,4**	**13,0**	**11,1**	**9,0**	**9,4**	**6,1**	**2,2**	**0,5**

4) The duration of exposure to sunlight

The duration of solar radiation during the growing season is given in Table 3. As can be seen from Table 3, the duration of sunshine is more pronounced in September-October and May-June. In general, the maximum duration of sun exposure varies from 140 to 374 days, the minimum from 96 to 335 days, and the average from 114 to 357 days. The duration of sunlight depends on a number of meteorological factors in addition to astronomical factors, i.e. cloudiness, which varies in time and space.

Table 3

At actinometric stations of Uzbekistan

The average monthly sum of the duration (hours) of sunlight

Station	**Month**									
	IX	**X**	**XI**	**XII**	**I**	**II**	**III**	**IV**	**V**	**VI**
Takhiotash	314	253	166	107	131	155	189	230	330	363
Tamdi	305	246	166	107	134	139	185	221	303	341
Tashkent	303	230	155	108	117	125	166	223	309	359
Fergana	293	225	145	96	112	116	151	204	279	335
Samarkand	307	237	169	125	128	131	162	219	312	370
Termez	315	260	190	141	140	146	181	230	329	374
Max	**315**	**260**	**190**	**141**	**140**	**155**	**189**	**230**	**330**	**374**
Min	**293**	**225**	**145**	**96**	**112**	**116**	**151**	**204**	**279**	**335**
Average	**306**	**242**	**165**	**114**	**127**	**135**	**172**	**221**	**310**	**357**

5) Photosynthetically active radiation

It is known that the process of photosynthesis takes place in the green leaves of plants due to the energy of sunlight. Numerous studies on the effects of sunlight on plants have shown that during photosynthesis, plants use only part of the solar spectrum, but not part of the wavelength between 0,38-0,71 mkm, and this part is called photosynthetic active radiation (PAR) (Chirkov Yu.I. 1988).

Under the influence of sunlight, the process of photosynthesis takes place in the green leaves of plants. Photosynthesis is the process of converting inorganic substances (water and carbon dioxide) into organic matter (protein, starch, etc.) at the expense of light energy absorbed in the plant leaf. A large part of the organic matter accumulated during photosynthesis is used by the plant during respiration to grow, develop and bear fruit.

Currently, the FAR incident at a point is calculated based on the measured values of the direct and scattered radiation incident at that point. B.I. Gulyaev, Kh.G. Tooming, N.A. Efimov as proposed the following equation to calculate the PAR (Babushkin L.N. 2004, Abdullayev A.Q. end ets.2008):

$$\Sigma Q_{PAR} = 0,43\Sigma S^1 + 0,57\Sigma D$$

where: Q_{PAR} - photosynthetically active radiation, S^1 - horizontal incident radiation, D - scattered radiation. Typically for practical purposes, Q_{PAR}, S^1, D are the sum values for the ten-day, monthly, and vegetation periods.

Based on the above data, the monthly sum of the amount of photosynthetically active radiation during the growing season of winter wheat was calculated using the Q_{PAR} formula (Table 4). The period from September to June is conventionally accepted as the vegetation period, because during this period all varieties of winter wheat ripen.

Table 4

At actinometric stations of Uzbekistan

Monthly sum of photosynthetic active radiation (MDj/m^2)

Station	Month										IX-VI
	IX	X	XI	XII	I	II	III	IV	V	VI	
Takhiatosh	262	203	124	86	114	150	224	286	382	398	2228
Tamdi	288	204	122	92	120	153	225	285	374	397	2259
Tashkent	283	193	115	84	106	134	201	270	359	398	2143
Ferghana	277	199	119	83	108	135	198	265	345	380	2108
Samarkand	296	206	132	104	124	144	211	271	370	410	2267
Termez	305	238	155	118	129	159	232	299	402	412	2449
SUMM	1710	1243	767	566	699	874	1291	1676	2234	2395	
Max	**305**	**238**	**155**	**118**	**129**	**159**	**232**	**299**	**402**	**412**	**2449**
Min	**262**	**193**	**115**	**83**	**106**	**134**	**198**	**265**	**345**	**380**	**2108**
Average	**285**	**207**	**128**	**94**	**117**	**146**	**215**	**279**	**372**	**399**	**2242**

As can be seen from Table 4, the annual total FAR fluctuates between 2108 MDj/m^2 (Fergana) and 2449 MDj/m^2 (Termez). The maximum value of FAR is observed in June and ranges from 380 MDj/m^2 (Fergana) to 412 MDj/m^2 (Termez), and the minimum value in December ranges from 83 to 118 MDj/m^2. The observation of the maximum value in the south of the republic (Termez) is related to the latitude of the total radiation and the distribution of its constituents.

CONCLUSIONS AND REVIEWS

The low monthly sum of 'S' is observed in industrial centers.

the monthly sum of the scattered radiation 'D' depends on astronomical factors (the height of the Sun above the horizon and the length of the day), the clarity of the atmosphere, and the albedo of the earth's surface and cloudiness.

less than 50% of the number of open days in irrigated areas occurs in November-April. The main minimum was observed in December.

The total radiation of PAR and the distribution of its constituents are related to latitude.

The actinomeric network in Uzbekistan has shown a minimum level of density, which suggests that in the future it is advisable to increase the number of monitoring stations to assess the energy resources of the regions.

In the future, it is necessary to analyze the above-mentioned quantities by observation periods, to study the phase variation of winter wheat crop and their effect on productivity elements.

In the effective use of solar radiation, it is necessary to assess its seasonal and annual variability, consider natural geographic distribution maps and zoning.

In order to increase the productivity of agricultural crops, it is necessary to pay full attention to the requirements of improving the light regime between plants, as well as to fully meet the requirements of agrotechnics, choosing the thickness of the crop bushes in the fields.

REFERENCES

1. Abdullaev Kh.M., Kratenko A.Yu. 2008. Radiation-energy resources and rice productivity in Uzbekistan. Tashkent, -123 p.
2. Abdullaev A.Q., Kholbaev G.X. Safarov E.Yu. 2009. Guidelines for the use of mathematical statistics, the use of computers and geographic information systems in finding related equations in agrometeorology. -Tashkent. -149 p.
3. Applied solar energy characteristics of Uzbekistan (reference materials). 1986.–Tashkent, SARNIGMI, –194 p.
4. Abdullayev A.Q., Arginboyev H.A., Abdullayev H.U. 2008. Agrometeorology. / Textbook for students.- Tashkent, - 397 p
5. Atlas of the Uzbek SSR. 1982. Part 1.-Moscow-Tashkent, GUGK, -124 p.
6. Atlas of the Uzbek SSR. 1985. Part 2.-Moscow-Tashkent, GUGK, -154 p.
7. Babushkin L.N. 2004. Basics of agrometeorology in Uzbekistan. -Tashkent.-228 p.

8. Babushkin L.N., Kogay N.A. 1964. Issues of geographic zoning of Central Asia and Uzbekistan // Proceedings of the Tashkent State University, vol. 231. -262 p.
9. Bannani F.K., Sharif T.A., Ben-Khalifa A.O.R. 2006. Estimation of monthly average solar radiation in Libya. Theoretical and Applied Climatology, volume 83, pages 211–215.
10. Codato G., Oliveira A. P., Soares J., Escobedo J.F., Gomes E. N.& Pai. A.D. 2008. Global and diffuse solar irradiances in urban and rural areas in southeast Brazil. Theoretical and Applied Climatology, volume 93, pages 57–73.
11. Chirkov Yu.I. 1988. Basics of agrometeorology - L .: Gidrometeoizdat, - 244 p.
12. Chizhevskaya M.P. 1962. Scattered radiation from observations in Voikovo // Proceedings of the MGO, issue 129.
13. Egamberdiev Kh.T. 1995. Features of the distribution of solar energy resources in Uzbekistan, taking into account the influence of anthropogenic factors. Auth.cand.diss. Tashkent. -24 p.
14. Egamberdiev Kh.T., Petrov Yu.V. 2018. The main regularities of the spatial and seasonal distribution of solar radiation parameters in Uzbekistan. Tashkent, -- 100 p. (-S.17-52.)
15. Gorbarenko E.V. 2020. Radiation Climate of Moscow. Russian Meteorology and Hydrology, volume 45, pages 478–487.
16. Gorodetsky O.A. and other 1991. Meteorology, methods and technical means of observation. –L. Hydrometeoizdat, -336 p.
17. Grupper S.R. 1998.Agrometeorological assessment of productivity of wheat in Uzbekistan. –Tashkent, SANIGMI, -156 p.
18. Chirkov Yu.I. 1988. Basics of agrometeorology - L .: Gidrometeoizdat, - 244 p.
19. Guidance for Hydrometeorological Station and posts. 2009. 11th Edition. Agrometeorological observations at stations and posts: 1 part. Basic agrometeorological observations. Tashkent, - 325 p.
20. Hua Zhang, Qing Yin, Teruyuki Nakajima, Nakata Mukai Makiko, Peng Lu&Jinhai He. 2013. Influence of changes in solar radiation on changes of surface temperature in China. Acta Meteorologica Sinicaб volume 27, pages 87–97.
21. Kholbaev G. Kh, Abdullaev A.K. 2020. Change of meteorological values in the autumn of Republic of Karakalpakstan and Khorezm region. International Journal of Advanced Research in Science, Engineering and Technology. Vol. 7, Issue 3, March. –PP. 123123-13130.
22. Kholbaev G.Kh., Abdullaev A.K., Egamberdiev Kh.T., Ergasheva Yu.Kh. 2020. Phenological Phases and Thermal Mode of the Winter Wheat in the Irrigated Areas in the Fergana Region. International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 05, –PP. 3833-3838.
23. Kholbaev G.Kh., Khadjaeva G. 2020. The air temperature changes in the irrigated areas of the republic of Karakalpakistan. SJIF Impact Factor: 7.001 EPRA International Journal of Research and Development (IJRD) Volume: 5. Issue: 5. May https://doi.org/10.36713/epra2016. www.eprajournals.com
24. Kholbaev G.Kh., Abdullaev A.K., Egamberdiev Kh.T. 2020. The vegetation period of winter wheat in southern areas of the Republic of Uzbekistan. Journal of Critical reviews. Vol 7, Issue 9, –PP. 122-125.
25. Kholbaev G.Kh., Egamberdiev Kh.T., Egamberdiev H.Kh. 2020. Change of meteorological values in autumn of Samarkand region. International Journal of Psychosocial Rehabilitation. Vol. 24, Issue 05,–PP. 6652-6660.
26. Kholbaev G.Kh., Egamberdiev Kh. T. 2021. Influence of Air Temperature Changes and Productivity Elements at Different Observation Periods. Alinteri J. of Agr. Sci. 36(1): -pp. 242-247
27. Mingzhong Xiao, Zhongbo Yu, Yuanzheng Cui. 2020. Evaluation and estimation of daily global solar radiation from the estimated direct and diffuse solar radiation Theoretical and Applied Climatology 140: PP. 983–992. https://doi.org/10.1007/s00704-020-03140-4
28. Nichiporovich A.A. 1966. Objectives of work on the study of photosynthetic activity of plants as a factor in productivity. –M: Nauka, - P. 7-50.
29. Olseth J.A.&Skartveit A. 2001. Solar irradiance, sunshine duration and daylight illuminance derived from METEOSAT data for some European sites. Theoretical and Applied Climatology, volume 69,pages239–252 (
30. Pivovarova Z.I. 1959. Characteristics of the radiation regime in clear weather // Proceedings of the MGO, issue 96.
31. Power H.C. 2003. Trends in solar radiation over Germany and an assessment of the role of aerosols and sunshine duration. Theoretical and Applied Climatology, volume 76, pages 47–63.
32. Scientific and Applied Reference Book on the Climate of the USSR. 1989. Series 3, Long-term data Part 1-6. Issue 19. Uzbek SSR. Book 1, 1989. -L.: Hydrometeoizdat, -279 p.
33. Sivkov S.I. 1968.Methods for calculating the characteristics of solar radiation. –L.: Hydrometeoizdat, - 230 p.
34. Stanhill G., Cohen S. 2005. Solar radiation changes in the United States during the Twentieth Century: evidence from sunshine duration measurements. J. Climate. 18. 1503–1512 10.1175/JCLI3354.1
35. Shulgin A.M. 1978. Solar radiation and plant. –L .: Gidrometeoizdat, - P. 3-45.
36. Tsubo M.& Walker S. 2005. Relationships between photosynthetically active radiation and clearness index at Bloemfontein, South Africa. Theoretical and Applied Climatology, volume 80, pages17–25.
37. Ulanova E.S. 1968. Methods of statistical analysis in agrometeorology. - L.: Gidrometeoizdat, - 198 p.
38. Ustenko G.P. 1963. Photosynthetic activity of plants in crops as the basis for the formation of high yields // In the book. Photosynthesis and questions of plant productivity. –M.: AN SSSR. - P. 37-70.
39. Vinnikov K.Ya. 1967. On the question of an objective analysis of actinometric quantities // Proceedings of the GGO, no. 208. - P. 88-95.

40. WMO Guidelines for the Calculation of Climatic Norms edition 2017. Geneva.-21 p.
41. Yang ZL, Zhang TB, Yi GH, et al. 2021. Erratum to: Spatio-temporal variation of Fraction of Photosynthetically Active Radiation absorbed by vegetation in the Hengduan Mountains, China. Journal of Mountain Science 18(6). https://doi.org/10.1007/s11629-019-5579-4
42. Zhengfang Wu, Haibo Du, Dongsheng Zhao, Ming Li, Xiangjun Meng&Shengwei Zong. 2012. Estimating daily global solar radiation during the growing season in Northeast China using the Ångström–Prescott model. Theoretical and Applied Climatology. Volume 108, pages 495–503.