ATROF-MUHIT VA TABIATNI MUHOFAZA QILISH TEXNOLOGIYALARI ILMIY-TADQIQOT INSTITUTI HUZURIDAGI ILMIY DARAJA BERUVCHI PhD.18/30.T.153.01 RAQAMLI ILMIY KENGASH

ATROF-MUHIT VA TABIATNI MUHOFAZA QILISH TEXNOLOGIYALARI ILMIY-TADQIQOT INSTITUTI

ALIXANOV BOXIR BORIEVICH

UGAM-CHATKAL MILLIY BOG‘IDA IQLIM O‘ZGARISHINING YER QOPLAMIGA TA’SIRINI BAHOLASH VA KELAJAK UCHUN PROGNOZLAR

11.00.05 – Atrof-muhitni muhofaza qilish va tabiiy resurslardan oqilona foydalanish

TEXNIKA FANLARI BO‘YICHA FALSAFA DOKTORI (PhD) DISSERTATSIYASI AVTOREFERATI

TOSHKENT – 2025

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Оглавление диссертации доктора философии (PhD) по техническим наукам

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TOSHKENT – 2025

Texnika fanlari falsafa doktori (PhD) dissertatsiyasi mavzusi O‘zbekiston Respublikasi Oliy ta’lim, fan va innovatsiyalar vazirligi huzuridagi Oliy attestatsiya komissiyasida № B2024.3.PhD/T180 raqam bilan ro‘yxatga olingan.

Dissertatsiya Atrof-muhit va tabiatni muhofaza qilish texnologiyalari ilmiy-tadqiqot institutida bajarilgan.

Dissertatsiya avtoreferati uch tilda (o‘zbek,ingliz, rus (rezyume)) institut veb sahifasi (ecoilm.uz, uznature.uz**)** va «Ziyonet» axborot ta’lim portalida (www.ziyonet.uz) joylashtirilgan.

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Dissertatsiya himoyasi Atrof-muhit va tabiatni muhofaza qilish texnologiyalari ilmiy-tadqiqot instituti huzuridagi ilmiy daraja beruvchi PhD.18/30.T.153.01 raqamli Ilmiy Kengashning 2025 yil «___» _____ soat ____ dagi majlisida bo‘lib o‘tadi. (Manzil: 100043, Toshkent sh., Chilonzor tumani, Bunyodkor shoh ko‘chasi, 7a uy. (tel.: (71) 277-69-83; faks.: (71) 277-89-22; e-mail.: eco_ilm@umail.uz).

Dissertatsiya bilan Atrof-muhit va tabiatni muhofaza qilish texnologiyalari ilmiy-tadqiqot instituti Axborot-resurs markazida tanishish mumkin (№___ raqami bilan ro‘yxatdan o‘tgan). (Manzil: 100043, Toshkent sh., Chilonzor tumani, Bunyodkor shoh ko‘chasi, 7a uy. (tel.: (71) 277-69-83; faks.: (71) 277-89-22; e-mail. eco_ilm@umail.uz:).

Dissertatsiya avtoreferati 202_ yil «___» _____ kuni tarqatilgan.

(202_ yil «___» _____ dagi _____ raqamli reestr bayonnomasi).

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KIRISH (falsafa doktori (PhD) dissertatsiyasi annotatsiyasi)

Dissertatsiya mavzusining dolzarbligi va zarurati. Jahonda iqlim o‘zgarishi sharoitida daryo havzalari, suv resurslari va atrof-muhitni muhofaza qilish borasida yer resurslaridan foydalanish, o‘simlik qoplamining o‘zgarishi, eroziya jarayonlari va suv sathining dinamikasi masalalariga katta e’tibor qaratilmoqda. Bugungi kunda dunyo miqyosida iqlim o‘zgarishining atrof-muhitga ta’siri tabiiy omillar va inson faoliyati natijasida yuzaga keladigan issiqxona gazlari emissiyalari orqali shakllanayotgan o‘zgaruvchi iqlim modellariga asoslanib tahlil qilinmoqda. Shuningdek, iqlim o‘zgarishiga moslashishni qo‘llab-quvvatlash va mintaqaviy miqyosda ta’sirni baholash maqsadida mintaqaviy iqlim modellarini amaliyotga joriy etish alohida ahamiyat kasb etmoqda. Europa, Yaponiya, Xitoy, Janubiy Koreya va AQSh kabi rivojlangan davlatlarda iqlim o‘zgarishining oqibatlarini kamaytirish va kelajakdagi ta’sirlarni bashorat qilish uchun geoaxborot texnologiyalariga asoslangan boshqaruv tizimlari ishlab chiqilmoqda. Shu jihatdan, iqlim o‘zgarishini mintaqaviy, davlat va region miqyosida kuzatib borish, uning yer qoplami, suv resurslari, tuproq eroziyasi, bioxilma-xillik, iqtisodiyot va odamlarga ta’sirini o‘rganish katta ahamiyatga ega.

Jahonda iqlim o‘zgarishi zamonaviy davrning eng dolzarb va jiddiy muammolaridan biri bo‘lib, bu borada tabiiy resurslar, atrof-muhit, inson salomatligi va suv resurslariga ta'sirini oldindan bashorat qilish bo‘yicha ilmiy izlanishlar olib borilmoqda. Bu yo‘nalishda, yog'ingarchilik intensivligi, suv oqimining dinamikasi, eroziya va yer resurslaridan foydalanish kabi tabiiy hodisalarning modelini ishlab chiqish muhim hisoblanadi. Shuningdek, iqlim o‘zgarishi ta’sirini aniqlash va yaqin hamda uzoq kelajakda yer va o‘simlik qoplamasining o‘zgarishini kuzatish uchun ko‘p spektrli sun’iy yo‘ldosh tasvirlari yordamida geoaxborot texnologiyalaridan foydalanishga qaratilgan tadqiqotlar olib borilmoqda.

Respublikamizda iqlim o‘zgarishining atrof-muhitga ta’sirini yumshatish, yog'ingarchilik o‘zgarishi va eroziya muammolarini hal etish uchun yangi texnologik yechimlar ishlab chiqilmoqda. Shuningdek, bu texnologiyalarni amalda qo‘llash bo‘yicha keng ko‘lamli tadbirlar amalga oshirilmoqda. 2022–2026 yillarga mo‘ljallangan Yangi O‘zbekiston taraqqiyot strategiyasida suv resurslarini boshqarish, raqamli texnologiyalarni joriy etish va monitoringda inson omilini qisqartirish kabi vazifalar belgilangan. Daryo havzalaridagi biomassaning o‘zgarishini tahlil qilish, oqimni boshqarish bo‘yicha ilmiy tadqiqotlar olib borish va ekologik oqim tushunchasiga asoslangan samarali modellarni ishlab chiqish masalalari dolzarb hisoblanadi.

O‘zbekiston Respublikasi Prezidentining 2023-yilning 31-maydagi “Ekologiya, atrof-muhitni muhofaza qilish va iqlim o‘zgarishi vazirligi faoliyatini samarali tashkil etish chora-tadbirlari to‘g‘risida”[1]gi PQ-171-sonli qarori, 2022-yil 28-yanvardagi “2022-2026-yillarga mo‘ljallangan Yangi O‘zbekistonning

taraqqiyot strategiyasi to‘g‘risida”[1]gi PF-60-son Farmoni, 2020-yil 10-iyuldagi PF-6024-sonli “O‘zbekiston Respublikasi suv xo‘jaligini rivojlantirishning 2020-2030-yillarga mo‘ljallangan konsepsiyasi”[2], 2019-yil 10-oktyabrdagi «2030-yilgacha bo‘lgan davrda O‘zbekiston Respublikasining atrof muhitni muhofaza qilish konsepsiyasini tasdiqlash to‘g‘risida» [3]gi PF-5863-son farmoni hamda mazkur faoliyatga tegishli boshqa me’yoriy-huquqiy hujjatlarda belgilangan vazifalarni amalga oshirishga ushbu dissertatsiya tadqiqoti ma’lum darajada xizmat qiladi.

Tadqiqotning respublika fan va texnologiyalari rivojlanishining ustuvor yo‘nalishlariga mosligi. Dissertatsiya ishi bo‘yicha tadqiqotlar fan va texnologiyalar rivojlanishining «Qishloq xo‘jaligi, biotexnologiya, ekologiya va atrof-muhit muhofazasi» ustuvor yo‘nalishiga doirasida bajarilgan.

Muammoni o‘rganilganlik darajasi. Oxirgi yillarda Markaziy Osiyoda iqlim o‘zgarishining o‘simliklar, er qoplami va kriosferaga ta’siri mahalliy va xalqaro olimlar tomonidan K.Adepoju, S.Adelabu, O.Fashae, F.Aditya, E.Gusmayanti, Sudrajat. J, N.Agaltseva, M.V.Bolgov, T.Yu.Spektorman, M. D. Trubetskova,B.Pulatov,V. E.Chub, I.Ahmad, D. Tang, T.Wang, M.Wang, B.Wagan, A.Pulatov, M.Barandun, J.Fiddes, V.R.Barros, C.B.Field, D.J.Dokken, M.D.Mastrandrea, K.J.Mach, A.Diebold, D.M.Frolov, A.V.Koshurnikov, V.E.Gagarin, E.I.Dodoboev, I.A.Nabiev, X.Fu, X.Wang, Y.Yang, F.Xikmatov, Sh.Murodov, M.Juliev va boshqalar tomonidan ilmiy tadqiqot ishlarini olib borganlar.

Iqlim o‘zgarishi sharoitida o‘simliklar, qor qoplami va yer qoplamiga ta’sirini baholash va bashorat qilish usullari va texnologiyalarini ishlab chiqishda V.E.Chub, I.Ahmad, D.Tang, T.Wang, M.Wang, B.Wagan, A.Pulatov, M.Barandun, J.Fiddes, V.R.Barros, C.B.Field, D.J.Dokken, M.D.Mastrandrea, K.J.Mach, A.Diebold, D.M.Frolov, A.V.Koshurnikov, V.E.Gagarin, E.I.Dodoboev, I.A.Nabiev, X.Fu, X.Wang, Y.Yang, F.Xikmatov, Sh.Murodov, M.Juliev va boshqa yuqoridagi masalalarini yechishda salmoqli natijalarga erishigan.

Shu bilan birga, iqlim o‘zgarishini o‘simliklar, qor qoplami va er qoplamiga ta’sirini baholash modellari asosida bir nechta zamonaviy innovatsion texnologiyalarini qo’llagan holda kelajak uchun bashoratlash usullari to’liq o’rganilmagan.

Dissertatsiya mavzusining dissertatsiya bajarilgan ilmiy-tadqiqot muassasasining ilmiy-tadqiqot ishlari rejasi bilan bog‘liqligi. Dissertatsiya tadqiqoti O‘zbekiston Respublikasi Vazirlar Mahkamasining 2022 yil 18 avgustdagi 458-sonli qarori «Atrof muhit va tabiatni muhofaza qilish texnologiyalari ilmiy-tadqiqot instituti faoliyatini yanada takomillashtirish chora-tadbirlari to‘g‘risidagi qarorining 3-ilovasi 8 bandigi GIS yordamida Toshkent

[1] O‘zbekiston Respublikasi Prezidentining 2022 yil 28-yanvardagi PF-60-son “2022-2026-yillarga mo‘ljallangan Yangi O‘zbekistonning taraqqiyot strategiyasi to‘g‘risida”gi Farmoni.

[2] O‘zbekiston Respublikasi Prezidentining 2020 yil 10 iyuldagi PF-6024-son “O‘zbekiston Respublikasi suv xo‘jaligini rivojlantirishning 2020-2030-yillarga mo‘ljallangan konsepsiyasi”gi Farmoni.

[3] O‘zbekiston Respublikasi Prezidentining 2019 yil 10 oktyabrdagi PF-5863-son “O‘zbekiston Respublikasi suv xo‘jaligini rivojlantirishning 2020-2030-yillarga mo‘ljallangan konsepsiyasi”gi Farmoni.

viloyati suv omborlarini atrofida ekotizim o‘zgarishini monitoring qilish bo‘yicha avtomatlashtirilgan dasturiy mahsulot yaratish (2022-2024) mavzularidagi loyihalar doirasida bajarilgan.

Tadqiqotning maqsadi. Iqlim o‘zgarishini Ugam-Chatkal milliy bog‘ining o‘simliklar, qor qoplami va er qoplamiga ta’sirini baholash va kelajak uchun prognoz qilishdan iborat.

Tadqiqotning vazifalari:

Iqlim o‘zgarishini o‘simliklar, qor qoplami va er qoplamiga ta’sirini baholash va kelajak uchun prognozlash modellari tahlili;

Iqlim o‘zgarishi (havo harorati, yog‘ingarchilik va tuproq harorati) tahlili Mann-Kendall test va Sen qiyaligi bilan, Bo‘stonliq va kengroq hudud uchun meteostansiya va sun’iy yo‘ldosh ma’lumotlari tahlili;

Bo‘stonliq tumanida oylik o‘simlik qoplamining o‘zgarishi tahlili NDVI, SAVI, Mann-Kendall test va Sen qiyaligi bilan va ularning iqlim parametrlari bilan bog‘liqligi;

CA-Markov modeli asosida Bo‘stonliq tumanida yerdan foydalanish va er qoplamining o‘zgarishi va kelajak uchun prognozlash;

2023-2065 yillar davri uchun iqlim, o‘simliklar va qor qoplamining prognozlash bo‘yicha ilmiy tavsiyalar ishlab chiqish.

Tadqiqotning obyekti sifatida Toshkent viloyati Bo‘stonliq tumanida joylashgan Ugam-Chatkal Milliy Bog‘i hisoblanadi.

Tadqiqotning predmetini. Bo‘stonliq tumanida iqlim o‘zgarishining qor qoplami, o‘simliklar va er qoplamiga ta’sirini masofaviy zondlash va statistik tahlillar orqali kompleks tahlil qilish va kelajak uchun prognoz qilishdan iborat.

Tadqiqot usullari. Tadqiqot jarayonida ekologiya va atrof-muhitni muhofaza qilish sohasida umum qabul qilingan usullardan foydalanilgan. Jumladan, geografik axborot tizimlari (GAT) va masofadan zondlash usullari, statistik usullar (Mann-Kendall testi, Sen qiyaligi va regressiya tahlili), mashina o‘rganish usullari (CA-Markov, Random forests, ARIMA va Prophet modellaridan foydalanilgan), dala tadqiqot usullari hamda mavjud me’yoriy hujjatlarda belgilangan usullar qo‘llanilgan.

Tadqiqotning ilmiy yangiligi quyidagilardan iborat**:**

Bostanliq tumanida kriosfera qoplami, ya’ni qor qoplami (NDSI indeksi orqali aniqlangan) va muz qoplami (NDSII indeksi orqali aniqlangan) 1991 yildan 2022 yilgacha kamayib borayotgani masofadan zondlash va statistik tahlil orqali yuqori ishonchligi aniqlanib (p_{ndsi}=0.0026, p_{ndsii} =0.0002) kelajak uchun Prophet mashina o‘rganish modeli yordamida keyingi 40 yil ichida tendensiya o’zgarishi prognoz qilingan;

Bostanliq tumani uchun 1991 yildan 2022 yilgacha kriosfera, vegetatsiya va iqlim jarayonlari o‘rtasidagi o‘zaro bog‘liqlikni chuqur statistik tahlil va masofadan zondlash usullari yordamida birinchi marta aniq miqdoriy baholashda kriosfera va vegetatsiya dinamikasining iqlim o‘zgarishlariga ta'siri baholangan;

Bostanliq tumani uchun Chimgan meteostansiyasida to‘plangan iqlim

parametrlari (yiliga yog‘ingarchilik miqdori, tuproq harorati va havo harorati) bilan ERA5 sun’iy yo‘ldosh ma’lumotlarida aynan shu iqlim parametrlari o‘rtasida statistik korrelyatsion bog’liqlik isbotlangan;

ARIMA mashina o‘rganish matematik modeli yordamida Chimgan meteostansiyasidan olingan iqlim ma’lumotlari hamda ERA5 sun’iy yo‘ldosh ma’lumotlari asosida 2023 yildan 2065 yilgacha bo‘lgan davr uchun iqlim o‘zgarishi va vegetatsiya o’zgarishi prognoz qilingan.

Tadqiqotning amaliy natijalari quyidagilardan iborat:

1991-2022 davrida uchun iqlim o‘zgarishi tahlili Mann-Kendall test va Sen qiyaligi bilan Chimgan stansiyasi ma’lumotlari va ERA5 sun’iy yo‘ldosh ma’lumotlari asosida aniqlangan;

Masofaviy zondlash va parametrik bo‘lmagan statistik tahlillar bilan NDVI va SAVI yordamida o‘simlik qoplami tahlil qilingan;

1991-2022 davrida uchun yerdan foydalanish va er qoplamini o‘zgarishi tahlili Random Forests yordamida va kelajak uchun prognoz (2035, 2045, 2055, 2065) CA-Markov modeli asosida bashorat qilingan;

2023 yildan 2065 yilgacha NDSI, NDVI, havo harorati, tuproq harorati va yog‘ingarchilik uchun ARIMA va Prophet modellari bilan kelajak prognoz qilingan.

Tadqiqot natijalarining ishonchliligi. Tadqiqot ham maydonda (*in situ*), ham masofaviy zondlash (*ex situ*) ma’lumotlaridan foydalangan holda olib borildi. Landsat tasvirlari uchun fazoviy echim 30 metr bo‘lib, bu er qoplamasining o‘zgarishlarini nisbatan yuqori aniqlik bilan tahlil qilish imkonini beradi. Faqat atmosfera tozalangan tasvirlar to‘plamidan foydalanildi, o‘simliklar tahlili va er qoplamasini tasniflash uchun 12% bulut qoplami va kriosfera tahlili uchun 8% bulut qoplami bilan izohlanadi.

Tadqiqot natijalarining ilmiy va amaliy ahamiyati. Tadqiqot natijalarining amaliy ahamiyati ARIMA natijalariga ko‘ra, UzHydromet o‘rtacha oylik havo harorati, tuproq harorati va yog‘ingarchilikni yuqori aniqlikda prognoz qilish mumkin. Iqlim o‘zgarishlarini prognoz qilish iqlim o‘zgarishiga moslashish va uni kamaytirish strategiyalarini, qishloq xo‘jaligi rivojlanishi va moslashish rejalarini, suv resurslarini barqaror boshqarishni, barqaror o‘tloqlarni boshqarishni va baland tog‘li hududlarda toshqinlar va ko‘chkilardan himoya qilishni rivojlantirishi bilan izohlanadi.

Tadqiqot natijalarining ilmiy ahamiyati LULC (yerdan foydalanish va yer qoplamasi) o‘zgarishlarini aniqlash tumandagi LULCning o‘tmishdagi rivojlanishini yaxshiroq tushunishga va yerdan foydalanish siyosatini takomillashtirishga yordam beradi. Yer qoplamasining prognoz ssenariylari mintaqaning yaqin va uzoq kelajakda qanday o‘zgarishini ko‘ra olishga yordam beradi, agar hozirgi tendensiyalar davom etsa, siyosatchilarga eng yomon holatlarning oldini olish uchun strategiyalarni ishlab chiqishda yordam beri bilan izohlanadi.

Tadqiqot natijalarining joriy qilinishi. Ugam-Chatkal milliy bog'ida iqlim o‘zgarishining yer qoplamiga ta'siri va kelajak uchun prognozlar bo‘yicha olingan natijalar asosida:

Toshkent viloyati Bo‘stonliq tumanining meteorologik parametrlari, yer qoplami va tuproq haroratini 1991 yildan 2022 yilgacha tahlil qilish asosida, yer qoplami, iqlim va vegetatsiyaning o‘zaro bog‘liqligi modellashtirilgan (Шўрланиш шароитида биодеҳқончилик халқаро маркази (ICBA) ilmiy tadqiqot tashkiloti, 2024 yil 26 iyundagi ICB/0879a-son ma’lumotnomasi). Natijada, Toshkent viloyati Bo‘stonliq tumani qishloq xo‘jaligi yerlariga iqlim o‘zgarishining ta’sirini masofadan turib kuzatish imkoniyati yaratilgan;

Toshkent viloyatida olib borilgan tadqiqot natijalariga ko’ra 1991-yildan 2022-yilgacha bo‘lgan davr uchun (32 yil) UCHNPning hozirgi holati masofadan zondlash va iqlim ma’lumotlari yordamida tahlil qilingan. Tahlil asosida yer foydalanish va yer qoplami uchun GAT xaritalari va iqlim ma'lumotlari uchun Mann-Kendall testi va Sen’s qiyalik statistik tahlili, vegetatsiya va kriyosfera ko‘rsatkichlari uchun qo‘llanilgan (O‘zbekiston Respublikasi Ekologiya, atrof-muhitni muhofza qilish va iqlim o‘zgarishi vazirligi 2024 yil 25 sentabrdagi 01/3-8725-son ma’lumotnomasi). Natijada nafaqat iqlim o‘zgarishining yer qoplami ta'sirini ilmiy tushunishni rivojlantiradi, balki atrof-muhitni muhofaza qilish va tabiiy resurslardan barqaror foydalanish uchun amaliy vositalarni ham taqdim etadi.

Tadqiqot natijalarining aprobatsiyasi. Mazkur tadqiqot natijalari xalqaro, respublika miqiyosidagi anjumanlarda va institut ilmiy kengashida muhokama qilingan va ma’qullangan, shu jumladan 2 ta xalqaro va 2 ta Respublika ilmiy-amaliy anjumanlarida muhokamadan o‘tkazilgan.

Tadqiqot natijalarining e’lon qilinganligi. Dissyertatsiya mavzusi bo‘yicha jami 8 ta ilmiy ishlar chop etilgan, shulardan, O‘zbekiston Respublikasi Oliy attestatsiya komissiyasining falsafa doktori (PhD) dissyertatsiyalari asosiy ilmiy natijalarini chop etish tavsiya etilgan ilmiy nashrlarda 8 ta maqola, jumladan 4 tasi xorijiy jurnal, 2 tasi milliy jurnalda hamda 2 tasi halqaro ilmiy konferenciyalarda.

Dissyertatsiyaning tuzilishi va hajmi. Dissyertatsiya tarkibi kirish, to‘rtta bob, xulosa, foydalanilgan adabiyotlar ro‘yxati va ilovalardan iborat. Dissyertatsiya hajmi 120 bet.

DISSERTATSIYANING ASOSIY MAZMUNI

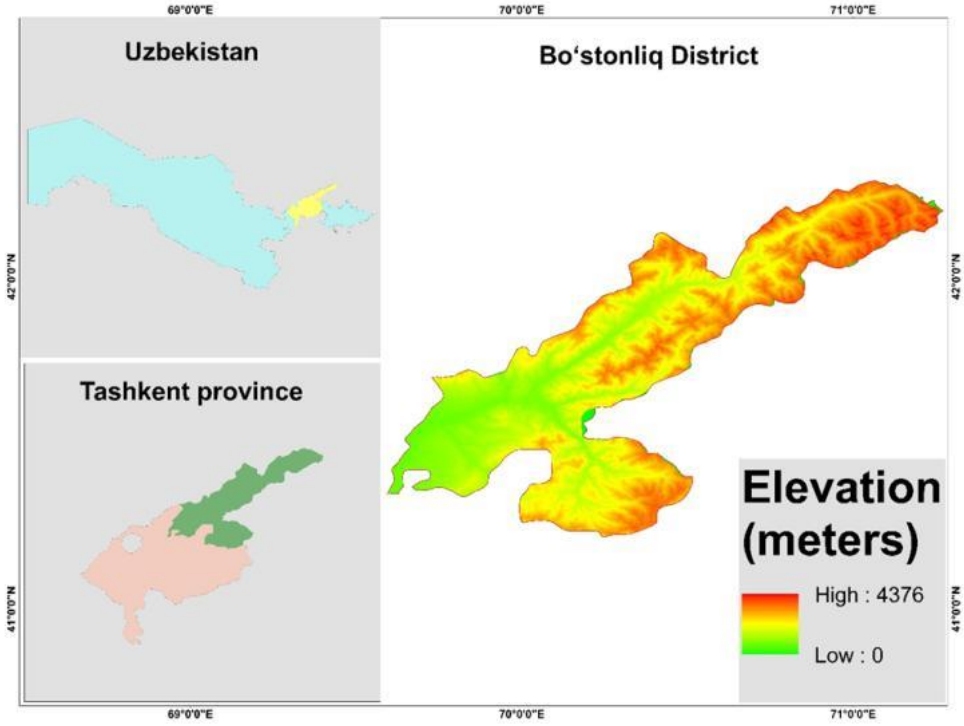
Dissyertatsiyaning **kirish** qismida mavzuning dolzarbligi va O‘zbekiston va jahonda zaruriyati asoslangan, maqsadi va vazifalari, tadqiqot ob’ekti va predmeti to‘g‘risida ma’lumotlar keltirib o‘tilgan. Bajarilgan tadqiqotlarning respublika fan va texnologiyalarni rivojlantirishning ustuvor yo‘nalishlariga mosligi ko‘rsatilgan va tadqiqotning ilmiy yangiligi, amaliy natijalari bayon etilgan. Olingan natijalarning nazariy va amaliy ahamiyati yoritib berilgan, tadqiqot natijalarini amaliyotga joriy etish, nashr etilgan ishlar va dissertatsiya tuzilishi bo‘yicha ma’lumotlar keltirilgan.

Dissertatsiyaning **«Adabiyotlar tahlili va metodologiya»** deb nomlangan **birinchi** bobida tadqiqot maydoni, metodologiya va adabiyotlar sharhini qamrab oladi. Birinchi bo‘limda, Toshkent viloyatining Bo‘stonliq tumanida joylashgan va Ugam Chatkal Milliy bog‘ini qamrab olgan o‘rganish hududi fizik, geografik, gidrologik, iqlimiy, flora va fauna hamda kriyosfer nuqtai nazaridan batafsil tasvirlanadi. Shuningdek, ushbu bo‘limda milliy park, uning tarixi va daryo tizimi haqida muhim ma’lumotlar keltirilgan.

Dissertatsiyaning ikkinchi bo‘limida, tadqiqot maqsadlari doirasida keng qamrovli adabiyot tahlili amalga oshirilgan. Ushbu bo‘lim bir nechta kichik bo‘limlardan iborat bo‘lib, ulardan biri “Iqlim o‘zgarishi” bo‘lib, global, mahalliy va milliy iqlim o‘zgarishi bo‘yicha chuqur tahlilni o‘z ichiga oladi. Unda iqlim o‘zgarishining kelajakdagi ssenariylari, mintaqa va mamlakat uchun amalga oshirilgan joriy tadqiqotlar, qo‘llanilgan usullar va materiallar, shuningdek, mavjud bilim bo‘shliqlari haqida ma’lumot berilgan. “Vegetatsiya” bo‘limida esa global biomassa va vegetatsiya qoplamasining hozirgi holati, masofadan zondlash va GIS vositalaridan foydalangan holda vegetatsiya qoplamasini tahlil qilish, keng qo‘llaniladigan vegetatsiya indekslari va ularning formulalari haqida ma’lumot berilib, mintaqa va mamlakatda vegetatsiya qoplamasining o‘zgarishini tahlil qilishda ushbu indekslardan foydalangan oldingi tadqiqotlar keltirilgan. “Kriyosfera” bo‘limida kriyosferaning tarkibiy qismlari, ularning farqlari va mahalliy ekotizim uchun ahamiyati ko‘rib chiqiladi. Shuningdek, kriyosferaning global va mahalliy holati, iqlim o‘zgarishining kriyosferaga ta’siri va masofadan zondlash texnologiyalarining kriyosfera monitoringida qo‘llanilishi haqida batafsil ma’lumotlar taqdim etilgan. Keyingi bo‘limda “Yer foydalanishi va yer qoplamasining o‘zgarishi” bo‘yicha yer foydalanishi va yer qoplamasining o‘zgarishi jarayoni, uning ta’rifi va masofadan zondlash texnologiyalarining ahamiyati tahlil qilinadi. Shuningdek, iqlim o‘zgarishining yer resurslariga ta’siri, Markaziy Osiyo, O‘zbekiston va Bo‘stonliq tumani bo‘yicha o‘tkazilgan tadqiqotlar natijalari yoritilgan. Uchinchi bo‘limning so‘nggi qismida “Model qilish va bashorat qilish” mavzusida iqlim va ob-havoni bashorat qilish uchun qo‘llaniladigan matematik modellash vositalari, metodlar va dasturlar ko‘rib chiqiladi. Turli mamlakatlarda olib borilgan tadqiqotlar asosida modellarning samaradorligi tahlil qilinadi. Shuningdek, O‘zbekistonda kelajakdagi ob-havo ssenariylarini bashorat qilish vositalarining yetishmasligi haqida muammo ochib berilgan. Ushbu bob orqali tadqiqotning ilmiy asoslari va metodologik yondashuvlari belgilangan bo‘lib, keyingi bo‘limlar uchun zarur ma’lumotlar taqdim etiladi.

Ushbu bobning «Metodologiya» deb nomlanga uchinchi bo’limida, bir nechta kichik boblardan iborat bo‘lib, ular quyidagilarni o‘z ichiga oladi: Usullar va materiallar, masofadan zondlash orqali vegetatsiya qoplamasini tahlil qilish, Yer qoplamasining masofadan zondlash klassifikatsiyasi, fazoviy ma'lumotlar, Ugam-Chatkal milliy parkidagi kriyosferani tahlil qilish, kriyosferaning masofadan zondlash tahlili va bashorat modellari. Ushbu bobda dissertatsiya va har bir

tadqiqot maqsadi uchun ishlatilgan usullar, materiallar, ma'lumotlar, dasturlar va matematik vositalar batafsil bayon etilgan. Iqlim ma'lumotlarini tahlil qilishda vegetatsiya indekslari va kriyosfera indekslari uchun parametrik bo‘lmagan statistik tahlil vositalari, ya'ni Mann-Kendall testi va Senning qiya-ligi keng qo‘llaniladi. Ushbu vositalar turli mamlakatlarda turli tadqiqotchilar va xalqaro tashkilotlar tomonidan keng qo‘llanilsada, O‘zbekistondagi ko‘plab tadqiqotchilar uchun, afsuski, ular noma'lumdir, garchi bu vositalar mustahkamligi va soddaligi bilan ajralib turadi.



1 - rasm. Tadqiqot obyekti.

$$S = \sum_{\{k=1\}}^{n} \sum_{k=j+1}^{n} sgn(y_j - y_k) \qquad (1)$$

Bu erda : *n*- umumiy elementlar soni, *k* va *j*: indekslar, bu yerda j-dan k-gacha qiymatlar olingan ; sgn: "signum" funksiyasi bo'lib, $y_j - y_k$ farqining ishorasini (musbat, manfiy yoki nol) belgilaydi.

Ularning parametrik statistik vositalar, masalan, Pearson korrelyatsiyasi va regressiya tahlili (bular ham dissertatsiya ishida qo‘llanilgan) bilan solishtirganda, no-normativ ma'lumotlarga juda mos keladi, monotonik tendensiyalarni aniqlaydi va osonlik bilan talqin qilinadi. Pearson korrelyatsiya koeffitsienti, ko‘pincha 'R' deb ataladi, ikkita o‘zgaruvchi o‘rtasidagi chiziqli munosabatning kuchi va yo‘nalishini o‘lchovchi statistik o‘lchovdir. Bu iqlim, kriyosfera va vegetatsiya o‘zgaruvchilari o‘rtasidagi munosabatlarni o‘lchash va har yili harorat, tuproq harorati va yog‘ingarchilikning tendensiyalarini aniqlash uchun qo‘llanildi."

$$Sen's\ slope = Median\left\{\frac{x_j - x_i}{j-i} : i < j\right\} \qquad (2)$$

Bu erda: Sen's slope: bu Senning qiyalik koeffitsienti bo'lib, vaqt seriyalaridagi trendni baholash uchun ishlatiladi; Median: Bu formulada hisoblangan barcha qiyaliklarning median qiymatini topishni anglatadi; $x_j - x_i$: Bu qiymatlar orasidagi o'zgarish miqdorini bildiradi, bu yerda jj-indeksidagi qiymatdan ii-indeksidagi qiymat ayiriladi; $j - i$: Bu ikkita indeks orasidagi vaqt yoki boshqa o'zgaruvchini bildiradi; $i < j$: Bu shart esa i-indeks j-indeksdan kichik bo'lishi kerakligini ko'rsatadi.

Vegetatsiya qoplamasi va kriyosfera qoplamasini tahlil qilish uchun bir nechta turli va keng sinovdan o‘tgan indekslar qo‘llanildi, bular jumlasiga Normalizatsiyalangan Farq Vegetatsiya Indeksi (NDVI), Tuproqni Moslashtirilgan Vegetatsiya Indeksi (SAVI), Normalizatsiyalangan Farq Qor Indeksi (NDSI), Normalizatsiyalangan Farq Muz Indeksi (NDGI) va Normalizatsiyalangan Farq Muz va Qor Indeksi (NDSII) kiradi. Ushbu indekslar 1991 yildan 2022 yilgacha bo‘lgan davrda Landsat tasvirlari yordamida qo‘llanildi.

$$\boldsymbol{NDVI = \frac{NIR - RED}{NIR + RED}}$$

$$\boldsymbol{SAVI = \frac{(NIR - RED) * (1 + L)}{NIR + RED + L}}$$

$$\boldsymbol{NDSI = \frac{(Green - SWIR)}{(Green + SWIR)}} \quad \textbf{(3)}$$

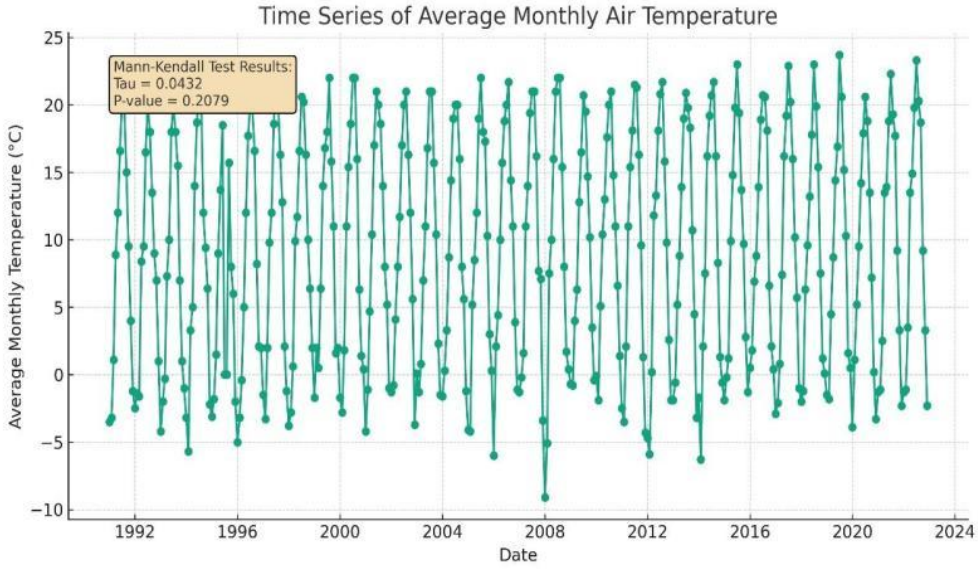
$$\boldsymbol{NDGI = \frac{(Green - RED)}{(Green + RED)}}$$

$$\boldsymbol{NDSII = \frac{(RED - SWIR)}{(RED + SWIR)}}$$

Bunda: NIR - yaqin infraqizil; RED - Qizil (o‘simliklarning yutilish darajasini va ularning sog‘lig‘ini aniqlashda muhim ahamiyatga ega); Green - yashil; SWIR - Qisqa to‘lqinli infraqizil (Shortwave Infrared).

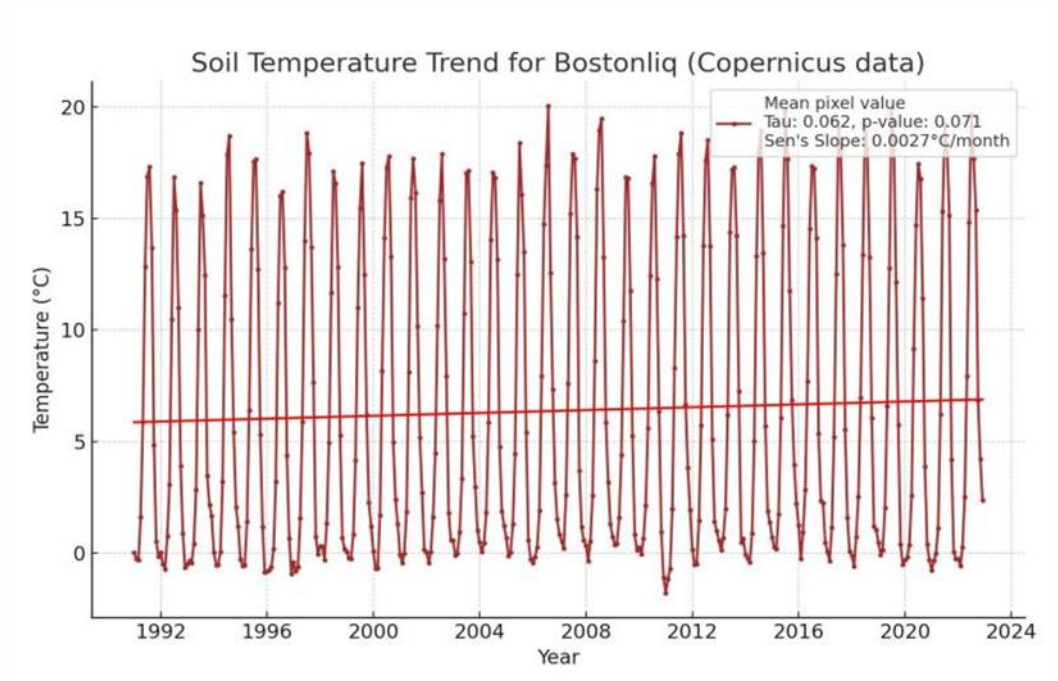
Dissertasiyaning **«1991-2022 yillarda Ugam-Chatkal Milliy Parkida iqlim o‘zgarishini Mann-Kendall testi va Sen qiyaligi yordamida tahlil qilish»** deb nomlangan **ikkinchi** bobida 1991-2022 davrida Mann-Kendall test va Senning qiyaligi yordamida Ugam-Chatkal milliy bog‘ida iqlim o‘zgarishi tahlil qilish' nomli tadqiqot 1991 yildan 2022 yilgacha Ugam-Chatkal milliy bog‘idagi o‘rtacha oylik havo harorati, o‘rtacha oylik tuproq harorati va oylik yog‘ingarchilik kabi iqlim parametrlarini o‘rganadi. Tadqiqotda parametrrik bo‘lmagan statistik usullar, ya’ni Mann-Kendall test va Senning qiyaligi yordamida Chimgan meteorologik stansiyasi va Copernicus ERA5 sun’iy yo‘ldosh o‘lchovlari ma’lumotlaridan

foydalangan. Mann-Kendall testi tendensiyalarni aniqlaydi, Senning qiyaligi esa bu tendensiyalarning kattaligini ko‘rsatadi (2-rasmga).



2-rasm. 1991 yildan 2022 yilgacha Bostonliq tumani uchun o‘rtacha oylik havo harorati grafiki (Chimgan meteorologik stansiyasi uchun).

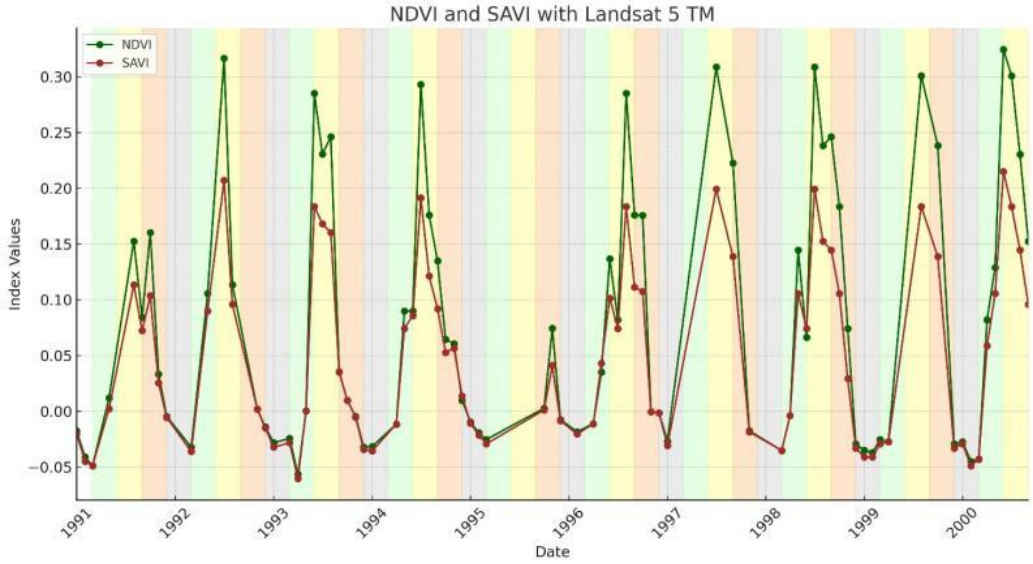
Natijalar havo harorati va yog‘ingarchilikda statistik jihatdan sezilarli tendensiyalar yo‘qligini ko‘rsatadi. Biroq, Bostonliq tumanida tuproq harorati deyarli sezilarli oshish tendentsiyasini ko‘rsatadi, p-qiymati 0.07 bo‘lib, isish tendentsiyasini ko‘rsatadi. Maydon ma'lumotlari va masofaviy zondlash ma'lumotlari o‘rtasidagi yuqori korrelyatsiyalar o‘lchovlarning ishonchliligini tasdiqlaydi, ammo yog‘ingarchilik tendentsiyalaridagi farqlar turli xil relieflarda aniq ma'lumotlarni to‘plash muammolarini ko‘rsatadi (3-rasm).



3-rasm. Bostonliq tumani uchun Copernicus iqlim ma’lumotlari asosida tuproq harorati uchun Mann-Kendall testi va Sen qiyaligi tahlili (1991-2022).

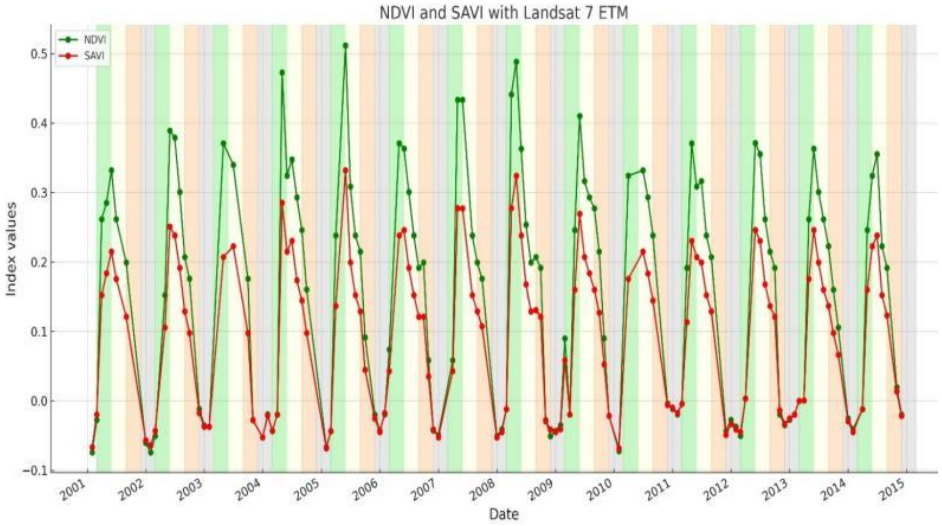
Bu bob hududning iqlimidagi nozik o‘zgarishlarni yaxshiroq tushunish uchun doimiy iqlim monitoringining ahamiyatini ko‘rsatadi. Havo harorati va yog‘ingarchilikda sezilarli o‘zgarishlar yo‘qligi tabiiy o‘zgarishlar yoki ko‘proq aniq ma'lumotlarga bo‘lgan ehtiyojni ko‘rsatishi mumkin. Tadqiqotning cheklovlari meteorologik sensorlarning aniqligi va baholash doirasini o‘z ichiga oladi, bu esa iqlim monitoringi infratuzilmasini takomillashtirish zarurligini ta'kidlaydi. Xulosa shundan iboratki, sezilarli o‘zgarishlar aniqlanmagan bo‘lsa-da, tuproq haroratida kuzatilgan tendentsiyalar iqlim o‘zgarishining dastlabki ta'sirlarini ko‘rsatishi mumkin, bu esa keyingi tadqiqot va monitoringni talab qiladi.

Dissertatsiyaning «**1991-2022 yillarda masofavy zondlash va statistik vositalar yordamida iqlim o‘zgarishining o‘simli qoplamaga ta'sirini tahlil qilish**» deb nomnalngan **uchinchi** bobda, 1991-2022 davrida masofaviy zondlash va statistik vositalar yordamida iqlim o‘zgarishining o‘simli qoplamiga ta'sirini tahlil qilish' nomli tadqiqot 1991 yildan 2022 yilgacha Ugam-Chatkal milliy bog‘idagi o‘simli qoplamining o‘zgarishlarini o‘rganadi. Landsat 5, 7 va 8 sun'iy yo‘ldosh tasvirlaridan olingan NDVI va SAVI indekslaridan foydalangan holda, bu bob korrelyatsion tahlil orqali o‘simli indekslari va iqlim o‘zgaruvchilari, masalan, tuproq va havo harorati va yog‘ingarchilik o‘rtasidagi bog‘liqlikni o‘rganadi (3 va 4-rasmlar).

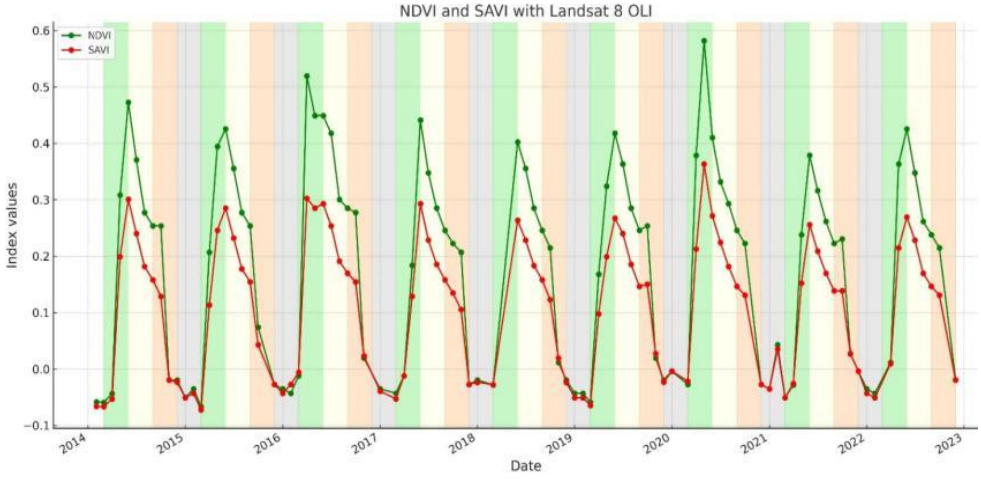


4-rasm. Landsat 5 TM yuzasi oydinliklaridan foydalangan holda tadqiqot hududi uchun NDVI va SAVI o‘rtacha oylik qiymatlari (1991–2000).

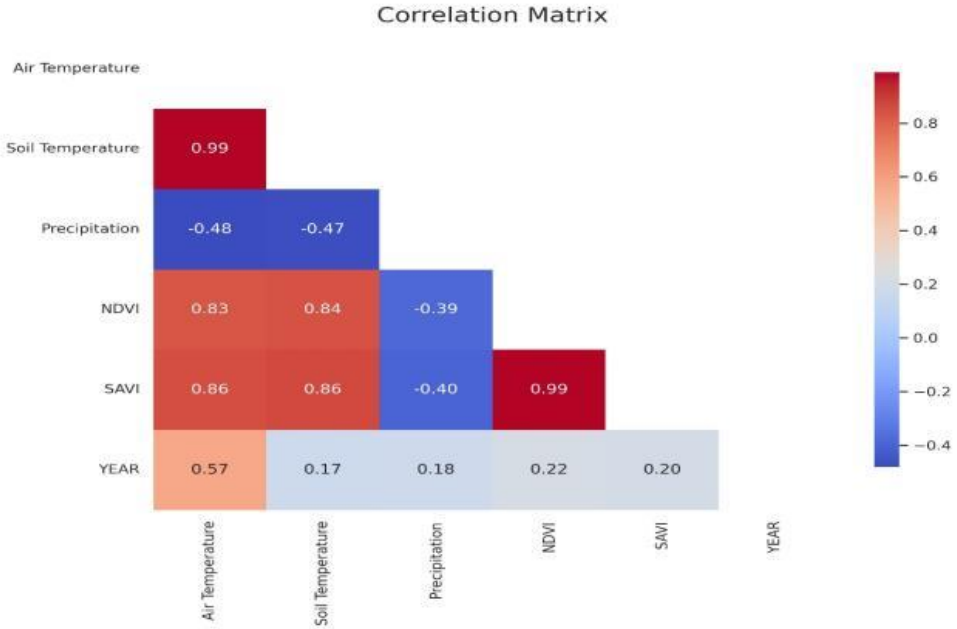
Bobda xulosa qilinishicha, Bostonliq tumanidagi o‘simlik qoplami sezilarli darajada oshgan, asosan tuproq va havo haroratining oshishi tufayli. O‘simlik qoplamining bu ijobiy tendentsiyasi issiqroq sharoitlar tufayli fotosintez faoliyatining oshishi bilan izohlanadi. Biroq, ushbu topilmalarning ishonchliligi tahlil qilingan tasvirlar soni bilan cheklangan, bu esa ko‘proq ma'lumotlarni qo‘shish orqali aniqroq natijalar olish mumkinligini ko‘rsatadi. Tadqiqot haroratning o‘simliklar dinamikasidagi muhim rolini ta'kidlaydi va bu tendentsiyalarni tasdiqlash uchun doimiy monitoring va kengroq ma'lumotlar to‘plamini¬ng zarurligini ta'kidlaydi (4,5 va 6 rasmlar).



5-rasm. Landsat 7 TM yuzasi oydinliklaridan foydalangan holda tadqiqot hududi uchun NDVI va SAVI o‘rtacha oylik qiymatlari (2001–2014).



6-rasm. Landsat 8 OLI yuzasi oydinliklaridan foydalangan holda tadqiqot hududi uchun NDVI va SAVI o‘rtacha oylik qiymatlari (2014–2022).

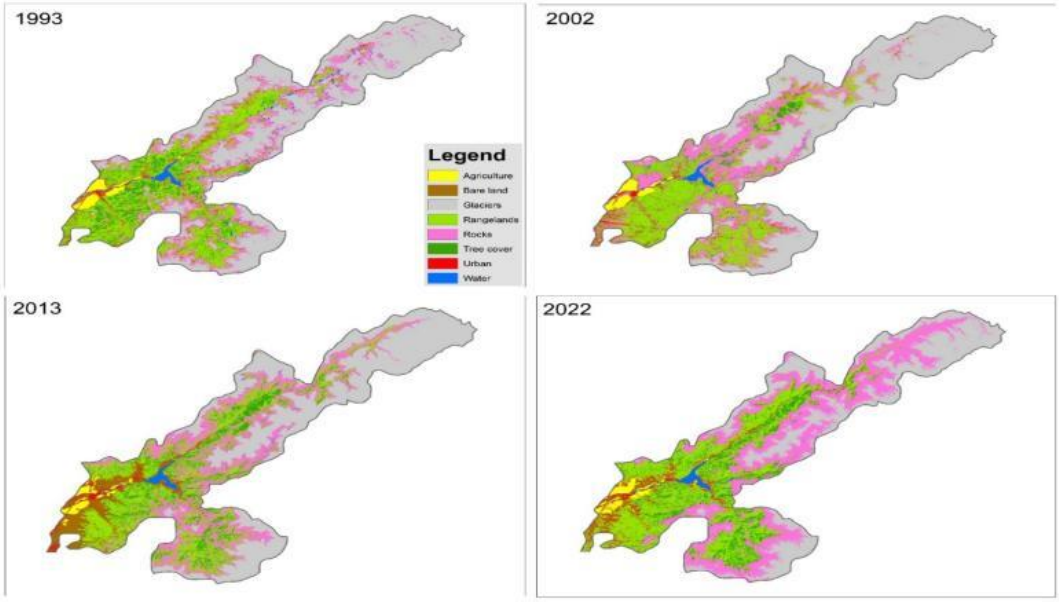


7-rasm. Iqlim va o‘rtacha o‘simlik indekslari o‘rtasidagi korrelyatsiya matritsasi.

Tahlil o‘simlik indekslari va tuproq va havo harorati o‘rtasida juda kuchli ijobiy korrelyatsiyani ko‘rsatdi, tuproq harorati kuchliroq ta'sir ko‘rsatdi. Aksincha, o‘simlik indekslari va yog‘ingarchilik o‘rtasida o‘rta kuchli manfiy korrelyatsiya topildi, bu shundan dalolat beradiki, o‘simliklar eng yuqori darajada yog‘ingarchilik past bo‘lgan davrlarda bo‘ladi. Mann-Kendall testi va Senning qiyaligi tahlili 1911-2022 davrida ham NDVI, ham SAVI indekslarida statistik jihatdan sezilarli ijobiy tendensiyani ko‘rsatdi, bu esa o‘simlik qoplamining oshganini ko‘rsatadi (7-rasm).

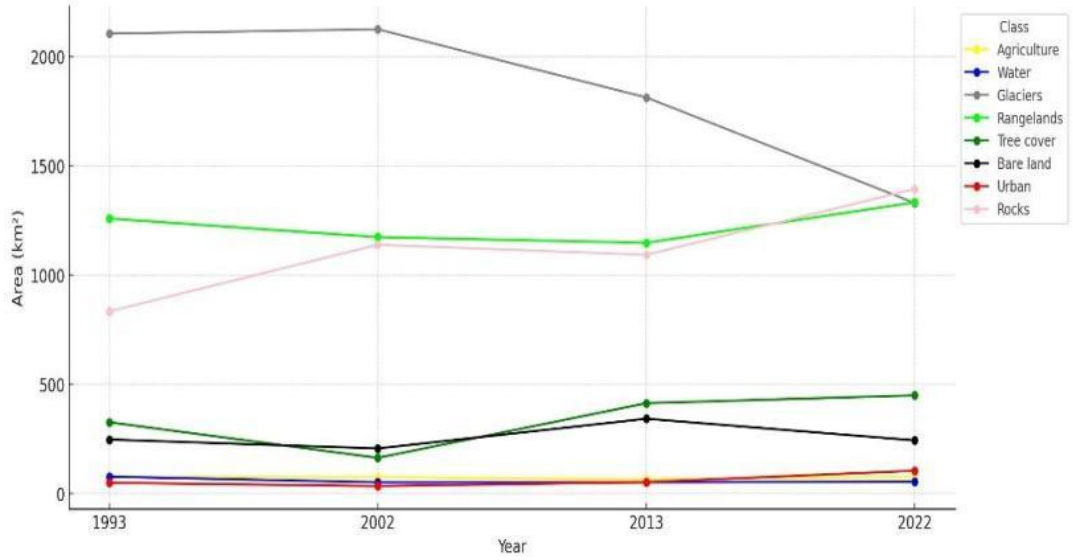
Dissertatsiyaning «**1991-2022 yillarda Ugam-Chatkal milliy parkida yerdan foydalanish va er qoplamining o‘zgarishi va masofavy zondlash yordamida kelajak prognozlari**» deb nomlangan **tortinchi** bobida, 1991-2022 davrida Ugam-Chatkal milliy bog‘ida yerdan foydalanish va er qoplamining o‘zgarishi va kelajak prognozlari' nomli tadqiqot 1991 yildan 2022 yilgacha Landsat tasvirlari asosida yerdan foydalanish va yer qoplamining (LULC) o‘zgarishlarini tahlil qiladi. Tadqiqot Bostonliq tumanini sakkizta toifaga ajratadi: yalang‘och erlar, suv, qishloq xo‘jaligi, tog‘lar, daraxt qoplami, o‘tloklar, muzliklar va shahar hududlari. Tasniflash Google Earth Engine (GEE) sun'iy yo‘ldoshlaridan yuqori aniqlikda olingan tasvirlar yordamida amalga oshirildi va 86% dan 88% gacha aniqlikka erishildi (8 –rasm).

Natijalar shundan dalolat beradiki, 1993 yilda 2015 km² bo‘lgan qor va muzliklar qoplami 2022 yilga kelib 1400 km² ga tushgan, bu global iqlim o‘zgarishi natijasida sodir bo‘lgan. Daraxt qoplami va shahar hududlari ko‘paygan, o‘tloklar va yalang‘och erlar esa o‘zgarib turibdi. CA-Markov modeli yordamida TerrSet dasturida kelajak LULC prognozlari uchta senariyda muzlik qoplamining yana-da kamayishini va o‘simlik qoplamining oshishini ko‘rsatadi: qiyin (o‘rta), yumshoq (yaxshi) va yomon (odatdagidek). Qiyin va yumshoq senariylar o‘xshash natijalarni prognoz qiladi, ammo yomon senariy tez shaharlashish va qishloq xo‘jaligining kengayishini ko‘rsatadi (9- rasm).



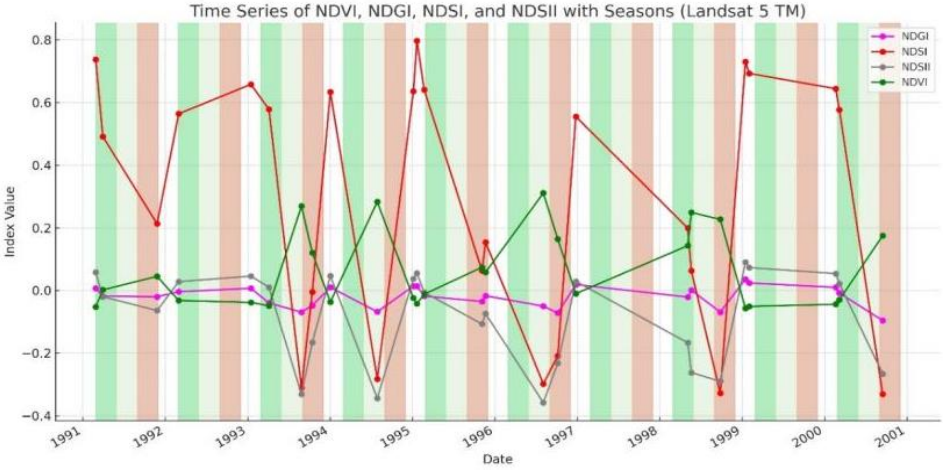
8-rasm. 1993–2022 davrida Bostonliq tumani (Ugam-Chatkal milliy bog‘i) yerdan foydalanish va er qoplamasining o‘zgarishi.

Bu bob iqlim o‘zgarishining davom etayotganligi er qoplamiga ta'sir ko‘rsatishda davom etishini va barqaror boshqaruv strategiyalarini ishlab chiqish zarurligini ko‘rsatadi. Topilmalar o‘tgan o‘zgarishlar va kelajak prognozlarini chuqur tushunishni ta'minlaydi, bu siyosatchilarga xabardorlikka asoslangan konservatsiya strategiyalarini ishlab chiqish va salbiy ta'sirlarni kamaytirishga yordam beradi. Tadqiqot masofaviy zondlash ma'lumotlarini ilg‘or mashinani o‘rganish texnikalari bilan integratsiya qilgan holda muhimligini ta'kidlaydi.



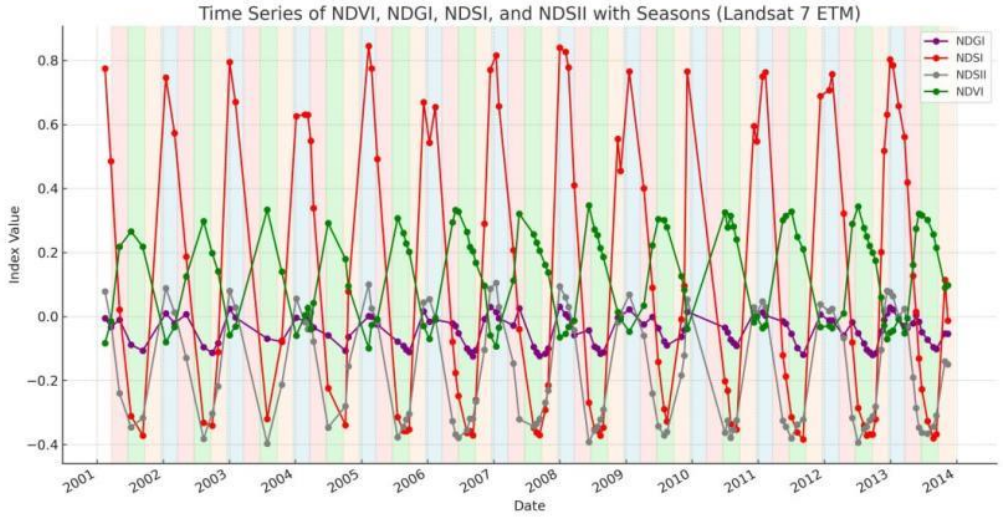
9-rasm. 1993-2022 davrida Bostonliq tumani (Ugam-Chatkal milliy bog‘i) yerdan foydalanish va er qoplamasining o‘zgarishi diagrammasi (1993-2022).

Dissertatsiyaning «**1991-2022 yillarda iqlim o‘zgarishining kriyosfera o‘zgarishiga ta'sirini masofavy zondlash yordamida tahlil qilish**» deb nomlangan **beshinchi** bobida, 1991-2022 davrida masofaviy zondlash yordamida iqlim o‘zgarishining kriyosfera o‘zgarishiga ta'sirini tahlil qilish' nomli tadqiqot Ugam-Chatkal milliy bog‘ida 1991 yildan 2022 yilgacha qor va muz qoplamasining o‘zgarishlarini baholaydi. Masofaviy zondlash ma'lumotlari va NDSI, NDGI va NDSII kabi indekslardan foydalangan holda, bu bob tendensiyalarni aniqlash uchun Mann-Kendall test va Senning qiyaligini qo‘llaydi (10, 11 va 12-rasmlar).

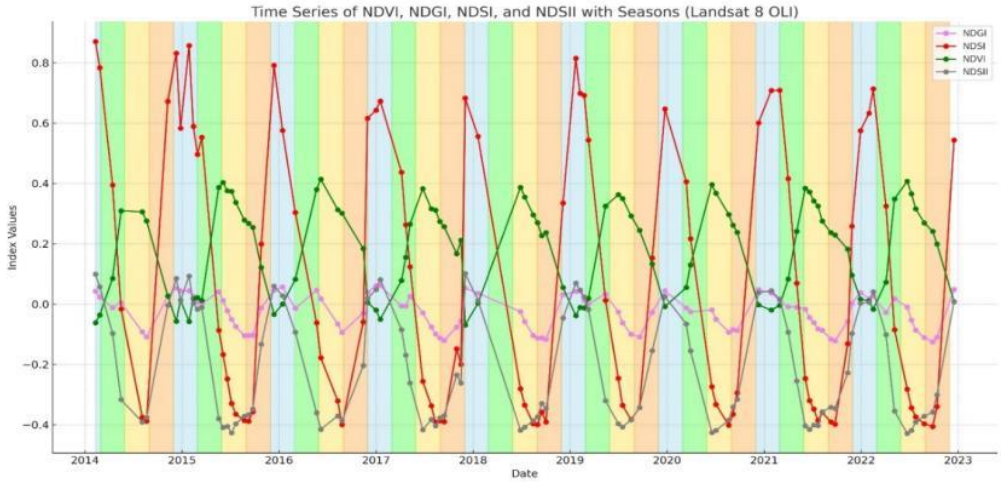


10-rasm. 1991–2000 yillarda Landsat 5 yordamida Ugam-Chatkal milliy bog‘idagi kriyosferaning vaqt qatorlari o‘zgarishi. Turli ranglar yilning turli fasllarini ko‘rsatadi.

Natijalar shundan dalolat beradiki, qor qoplami (NDSI va NDSII) sezilarli darajada kamaygan, statistik jihatdan sezilarli kamayish tendensiyalari mavjud. Muzliklar qoplami (NDGI) uzoq muddatli tendensiyalarisiz kichik o‘zgarishlarni ko‘rsatdi. Kriyosfera indekslari va tuproq harorati o‘rtasidagi manfiy korrelyatsiya issiq harorat qor va muz qoplamining kamayishiga olib kelayotganini ko‘rsatadi (13 - rasm). Tadqiqot kriyosferaga iqlim o‘zgarishining salbiy ta'sirlarini boshqarish uchun doimiy monitoring zarurligini ta'kidlaydi, bu esa suv resurslarini boshqarish va ekologik muvozanat uchun muhimdir.

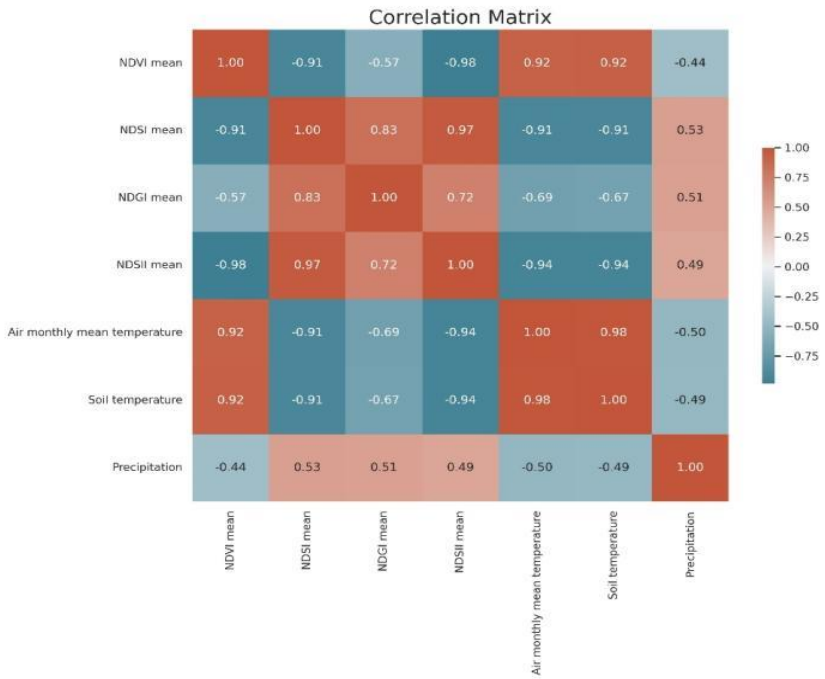


11-rasm. 2001–2014 yillarda Landsat 7 ETM yordamida Bostonliq tumanidagi kriyosferaning vaqt qatorlari tahlili.



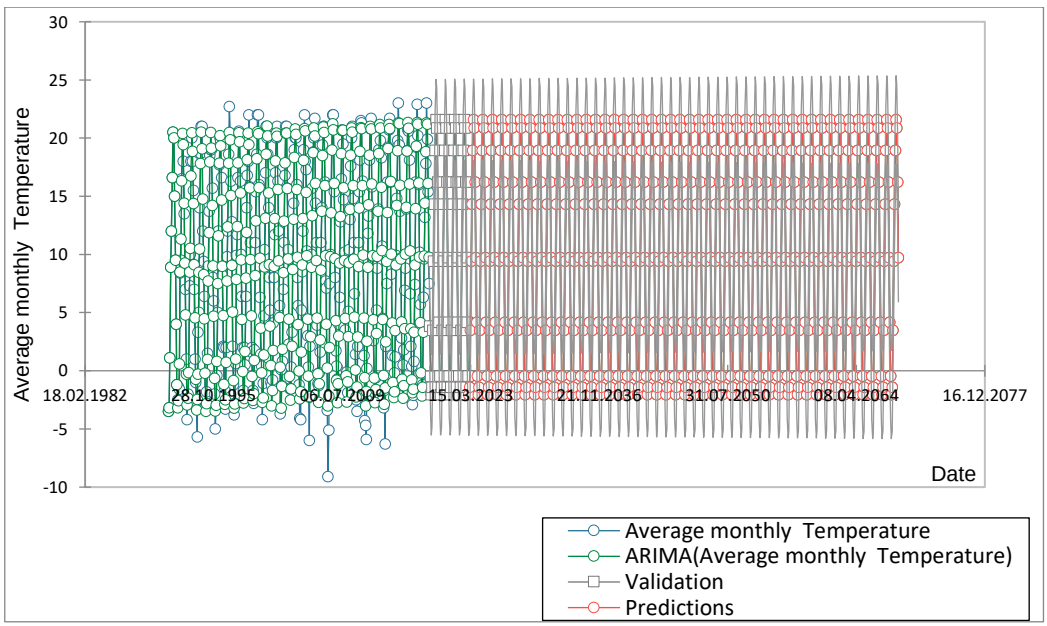
12-rasm. 2014–2022 yillarda Landsat 8 OLI yordamida Bostonliq tumanidagi kriyosferaning vaqt qatorlari tahlili.

Xulosalar shundan iboratki, kriyosfera hududlarining kamayishiga javoban suv resurslarini va ekologik barqarorlikni saqlash uchun strategik intervensiyalarni amalga oshirish zarurligi ta'kidlanadi. Tadqiqot iqlim o‘zgaruvchilari va kriyosfera dinamiki o‘rtasidagi bog‘liqlik haqida muhim ma'lumotlarni taqdim etadi, moslashuvchan boshqaruv strategiyalarining ahamiyatini ta'kidlaydi.

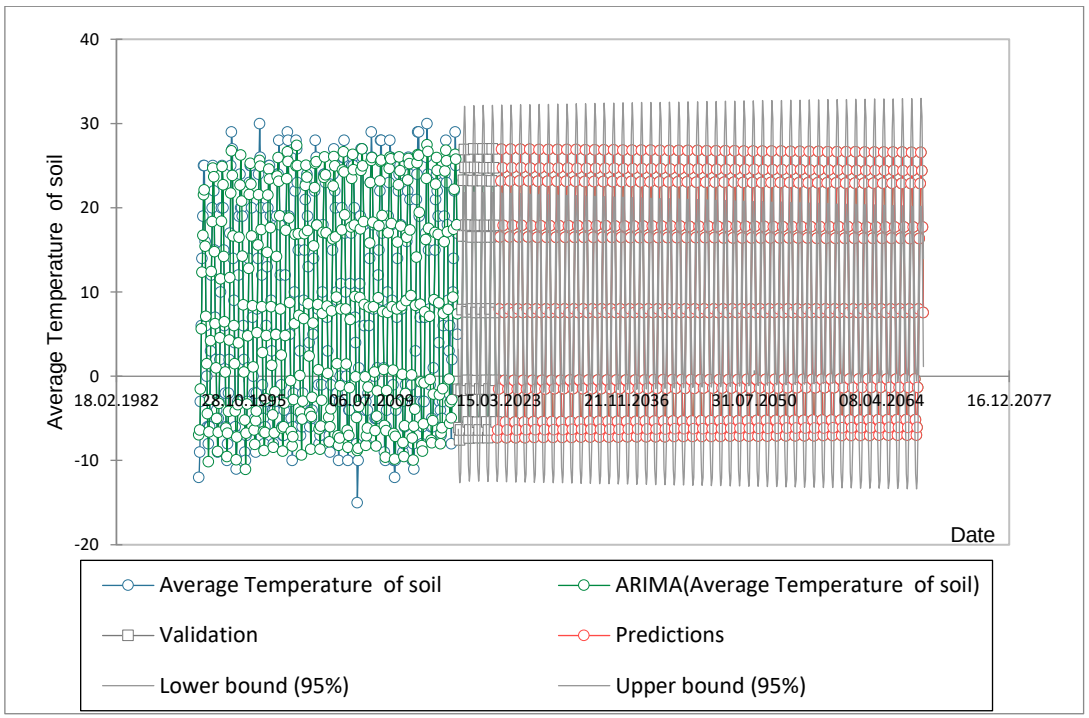


13-rasm. Iqlim, kriyosfera va o‘rtacha o‘simlik indekslari o‘rtasidagi korrelyatsiya matritsasi.

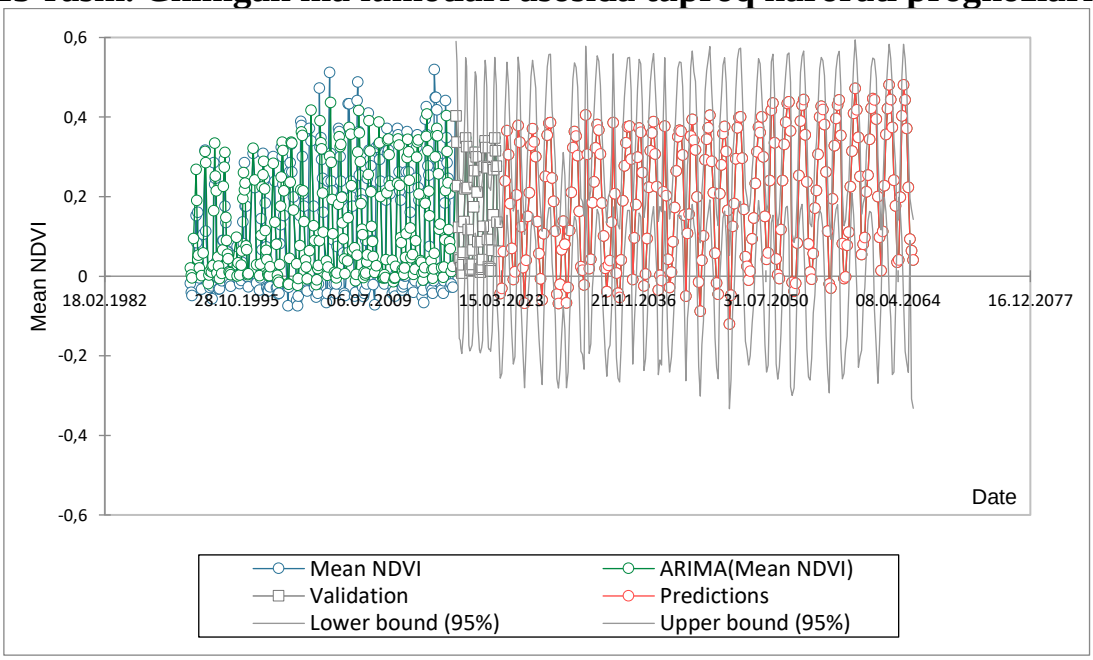
Dissertatsiyaning “**ARIMA va Prophet modellari yordamida o‘simliklar, iqlim va qor qoplamining kelajak prognozlari**” deb nomlangan **oltinchi** bobida nomli tadqiqot 2023 yildan 2065 yilgacha oylik tuproq harorati, havo harorati, yog‘ingarchilik, NDVI va NDSI bo‘yicha kelajak tendensiyalarni prognoz qilish uchun ARIMA va Prophet modellardan foydalanadi. SARIMA modeli havo va tuproq harorati bo‘yicha yaxshi validatsiya natijalarini ko‘rsatdi, ammo yog‘ingarchilikning yuqori o‘zgaruvchanligi tufayli faqat o‘rta natijalarni ko‘rsatdi (14, 15 va 16 rasmlar).



14-rasm. Chimgan ma'lumotlari asosida keyingi 40 yil uchun havo harorati prognozlari.



15-rasm. Chimgan ma'lumotlari asosida tuproq harorati prognozlari.



16-rasm. ARIMA modeli yordamida kelajak uchun NDVI prognozlari.

Prognozlar Chimgan ma'lumotlari asosida iqlim parametrlar bo‘yicha statistik jihatdan sezilarli tendensiyalarni ko‘rsatmaydi, ammo ERA5 ma'lumotlari havo haroratining biroz oshishi va yog‘ingarchilikning kamayishini ko‘rsatadi. Bostonliq tumani uchun tuproq harorati prognozlari deyarli statistik jihatdan sezilarli oshish tendensiyasini ko‘rsatadi, bu qor qoplami va erning isishiga ta'sir ko‘rsatishi mumkin. NDVI qor qoplamining kamayishi va o‘simliklar bilan almashtirilishi tufayli oshishi prognoz qilinmoqda. NDSI ma'lumotlarining yetishmasligi tufayli foydalangan Prophet modeli qor qoplamining sezilarli kamayishini prognoz qiladi, bu suvni boshqarish strategiyalariga moslashuvchanlikni talab qiladi.

XULOSALAR

Ugam-Chatkal Milliy Bog‘ida iqlim o‘zgarishining yer qoplamiga ta‘siri baholash va kelajak uchun prognozlar mavzusidagi falsafa doktori (PhD) dissertatsiyasi boy‘icha olib borilgan tadqiqotlar asosida qyuidagi xulosalar taqdim etildi:

1. 1991-2022 yillar uchun Chimgan meteorologiya stansiyasining dala ma’lumotlari va ERA5 ma’lumotlaridan foydalangan holda keng qamrovli iqlim tahlili o‘tkazildi. Sun'iy yo'ldosh va dala ma'lumotlari bir-biriga muvofiqligi tekshirildi va yuqori korrelyatsiyani ko'rsatdi (0.97-0.98). Chimgan stansiyasi, Bo‘stonlik tumani (ERA5) va 30 000 kvadrat kilometrni egallagan katta mikroiqlim maydoni (ERA5) uchun havo harorati, tuproq harorati va yog‘ingarchilik kabi iqlim parametrlari o‘rganildi. Natijalar qor yog‘ishining pasayishi (tau=-0.016, p=0.048), tuproq haroratining oshishi (tau=0.065; p=0.07) va yog‘ingarchilikning nisbiy barqarorligini (tau =-0.044, p =0.19) ko‘rsatdi.
2. 1991-2022 yillar davomida o‘rganilayotgan hududning vegetatsiya tahlili Landsat tasvirlari va o‘simlik ko‘rsatkichlari (NDVI, SAVI) hamda parametrik bo‘lmagan asboblar (Mann-Kendall testi va Sens qiyaliklari) ikkala indeks uchun ham o‘simliklarning statistik jihatdan sezilarli o‘sish tendentsiyasini ko‘rsatdi (tau=0.12, p-qiymati =0.0019). SAVI indeksi NDVI (R=0.86) ga qaraganda tuproq va havo harorati bilan ko'proq bog'liq. Ikkala indeks ham yog'ingarchilik bilan salbiy korrelyatsiyani ko'rsatdi (R= -0.47).
3. Tadqiqot hududining yer foydalanishi va yer qoplami bo‘yicha kompleks tahlili natijalariga ko‘ra, kriosfera (qor qoplami, muzliklar) 1993-yildan 2022-yilgacha 30 % ga kamaygani aniqlangan. Bundan tashqari, daraxt qoplami sezilarli o‘sishni ko‘rsatadi (+25 %), toshlar (+34 %) va aholi yashash joylari (+30 %). CA-Markov modeli yordamida amalga oshirilgan kelajak prognozlari muzliklarning tobora kamayishini va ularning o‘rnini tosh va o‘simlik qoplami egallashini ko‘rsatadi.
4. Kriosfera tahlili masofadan zondlash indekslari (NDSI, NDGI, NDSII) yordamida amalga oshirilib, tadqiqot hududi uchun qor va muz qoplamining kamayishini ko‘rsatdi (tau = -0.13, p = 0.0026), muzlik qoplami esa barqaror o‘zgarishsiz qoldi (tau = 0.026, p = 0.54). NDSI va NDSII tuproq harorati bilan juda kuchli salbiy korrelyatsiyani ko‘rsatdi (-0.91 va -0.94) va yog‘ingarchilik bilan o‘rtacha ijobiy korrelyatsiyani aniqladi (0.53 va 0.49). NDGI (muzliklar indeksi) esa tuproq va havo harorati bilan kichikroq bog‘liqlikka ega (-0.69 va -0.67), lekin yog‘ingarchilik bilan xuddi shunday ijobiy bog‘liqlikni ko‘rsatdi (0.51). Uchala kriosfera indeksi NDVI bilan salbiy bog‘liqlikka ega bo‘lib, NDSI va NDSII ancha yuqori salbiy bog‘liqlarni namoyon etdi (R =-0.97).
5. NDVI va kriosfera indekslari (NDSII), shuningdek, yog‘ingarchilik, havo harorati va tuproq harorati bo‘yicha ARIMA va Prophet modellaridan foydalanib amalga oshirilgan kelajak prognozlari quyidagi natijalarni ko‘rsatdi: NDSII (qor va muz indeksi) keyingi 40 yil davomida kamayishda

davom etadi (tau = -0.15, p = 0.02), NDVI esa o‘sishda davom etadi, bu esa tadqiqot hududining qayta o‘simlik qoplami bilan qoplanishini ko‘rsatadi (tau = 0.11, p = 0.04). Tuproq harorati (ERA5) hudud bo‘ylab asta-sekin ko‘tariladi (tau = 0.09, p = 0.06), havo harorati esa asta-sekin pasayadi, biroq natijalar bu haqda ishonch bilan xulosa qilish uchun statistika jihatidan ahamiyatli emas (tau = 0.04, p = 0.1). Faqat yog‘ingarchilik keyingi 40 yil davomida barqaror qoladi.

6. Umumiy xulosa shuni ko‘rsatadiki, tadqiqot hududi global iqlim o‘zgarishidan ta‘sirlanmoqda, xususan, yillik yog‘ingarchilik tendensiyalarida o‘zgarishlar kuzatilmoqda: qor yog'ish miqdorining kamayishi va yomg'ir yog‘ish miqdorining ortishi natijasida qor qoplami kamayib, uning o'rnini o‘simlik qoplami egallamoqda.

SCIENTIFIC COUNCIL AWARDING SCIENTIFIC DEGREES PhD.18/30.T.153.01 AT SCIENTIFIC-RESEARCH INSTITUTE OF ENVIRONMENTAL AND NATURE PROTECTION TECHNOLOGIES

RESEARCH INSTITUTE OF ENVIRONMENT AND NATURE CONSERVATION TECHNOLOGIES

ALIKHANOV BOKHIR BORIYEVICH

ASSESSMENT OF THE IMPACT OF CLIMATE CHANGE ON THE LAND COVER OF UGAM-CHATKAL NATIONAL PARK AND FORECASTING FOR THE FUTURE

11.00.05 – Environmental protection and rational use of natural resources

DISSERTATION ABSTRACT OF THE DOCTOR OF PHILOSOPHY (PhD) ON TECHNICAL SCIENCES

TASHKENT – 2025

The topic of doctoral dissyertation (PhD) on technical science was registyered at the Supreme Attestation Commission at the Ministry of Higher Education, Science and Innovations of the Republic of Uzbekistan with number № B2024.3.PhD/T180

The doctoral dissyertation was prepared at the Research Institute of Environment and Nature Protection Technologies.

The abstract of the dissyertation in three languages (uzbek, english, russian,(resume)) is placed on website of institute (ecoilm.uz, uznature.uz) and information-educational portal ZiyoNet at the address (www.ziyonet.uz).

Scientific advisor:	**Pulatov Baxtiyor Alimovich** Doctor of technical science, associate professor
Official opponents:	**Juliyev Mukhiddin Komilovich** Doctor of biological science, associate professor
	Gaffarov Husen Shirinovich Doctor of Philosophy in technical science (PhD), senior researcher
Leading organization:	**National University of Uzbekistan after Mirzo Ulugbek**

The defense of the thesis will be held "____" _____ 202_ at ___ hours at the meeting of the Scientificcouncil № PhD.18/30.T.153.01 at the Research Institute of Environment and Nature Protection Technologies (Address: 100043, Tashkent city, Chilanzor district, Bunyodkor street, house 7a. Tel: (71)277-69-83; faks.: (71)277-89-22; e-mail.: ecoilm.uz).

The dissertation can be viewed at the at the Information Resource Center of the Research Institute of Environment and Nature Protection Technologies (Address: 100043, Tashkent city, Chilanzor district, Bunyodkor street, house 7a. Tel: (71) 277-69-83; faks.: (71)277-89-22; e-mail.: ecoilm.uz).

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INTRODUCTION (Abstract of the PhD Dissertation)

Relevance and necessity of the dissertation topic. In the context of global climate change, significant attention is being given to the issues of land resource utilization, changes in vegetation cover, erosion processes, and water level dynamics concerning river basins, water resources, and environmental protection. Today, the impact of climate change on the environment is being analyzed based on changing climate models that are shaped by natural factors and greenhouse gas emissions resulting from human activities. Additionally, the implementation of regional climate models in practice is gaining particular importance to support climate change adaptation and assess its impact at the regional level. Developed countries such as Europe, Japan, China, South Korea, and the United States are developing geo-information technology-based management systems to mitigate the consequences of climate change and predict future impacts. From this perspective, monitoring climate change at the regional, national, and local levels and studying its effects on land cover, water resources, soil erosion, biodiversity, the economy, and human populations is of great significance.

Climate change is one of the most pressing and serious global challenges of the modern era, leading to ongoing scientific research aimed at forecasting its effects on natural resources, the environment, human health, and water resources. In this regard, it is crucial to develop models of precipitation intensity, water flow dynamics, erosion, and land use. Additionally, research is being conducted to analyze the effects of climate change and to monitor changes in land and vegetation cover in both the near and distant future using multispectral satellite imagery and geo-information technologies.

In our Republic, efforts are being made to mitigate the environmental impacts of climate change, address precipitation variability, and solve erosion problems by developing new technological solutions. Furthermore, large-scale initiatives are being implemented to apply these technologies in practice. The New Uzbekistan Development Strategy for 2022–2026 outlines tasks related to water resource management, the implementation of digital technologies, and reducing human influence in monitoring. Scientific research is also being conducted on analyzing biomass changes in river basins, managing water flow, and developing effective models based on the concept of ecological flow.

This dissertation research contributes, to some extent, to the implementation of the tasks outlined in the Presidential Decree of the Republic of Uzbekistan No. PQ-171, dated May 31, 2023, "On Measures to Effectively Organize the Activities of the Ministry of Ecology, Environmental Protection, and Climate Change," the Presidential Decree No. PF-60, dated January 28, 2022, "On the New Uzbekistan Development Strategy for 2022–2026," the Presidential Decree No. PF-6024, dated July 10, 2020, "On the Concept of Development of the Water Management System of the Republic of Uzbekistan for 2020–2030," and the Presidential Decree No. PF-5863, dated October 10, 2019, "On the Approval of the Environmental Protection Concept of the Republic of Uzbekistan until 2030," as well as other relevant normative-legal documents related to this field.

Alignment of the research with priority areas of science and technology development in the Republic. The research within this dissertation aligns with the priority area V: "Agriculture, Biotechnology, Ecology, and Environmental Protection."

Degree of problem exploration. In recent years, the impact of climate change on vegetation, land cover, and the cryosphere in Central Asia has been studied by both local and international scientists, including K. Adepoju, S. Adelabu, O. Fashae, F. Aditya, E. Gusmayanti, Sudrajat J., N. Agaltseva, M. V. Bolgov, T. Yu. Spektorman, M. D. Trubetskova, V. E. Chub, I. Ahmad, D. Tang, T. Wang, M. Wang, B. Wagan, A. Pulatov, M. Barandun, J. Fiddes, V. R. Barros, C. B. Field, D. J. Dokken, M. D. Mastrandrea, K. J. Mach, A. Diebold, D. M. Frolov, A. V. Koshurnikov, V. E. Gagarin, E. I. Dodoboev, I. A. Nabiev, X. Fu, X. Wang, Y. Yang, F. Khikmatov, Sh. Murodov, M. Juliev, and others.

In developing methods and technologies for assessing and predicting the impact of climate change on vegetation, snow cover, and land cover, V. E. Chub, I. Ahmad, D. Tang, T. Wang, M. Wang, B. Wagan, A. Pulatov, M. Barandun, J. Fiddes, V. R. Barros, C. B. Field, D. J. Dokken, M. D. Mastrandrea, K. J. Mach, A. Diebold, D. M. Frolov, A. V. Koshurnikov, V. E. Gagarin, E. I. Dodoboev, I. A. Nabiev, X. Fu, X. Wang, Y. Yang, F. Khikmatov, Sh. Murodov, M. Juliev, and other researchers have made significant contributions to solving these issues.

At the same time, methods for predicting the impact of climate change on vegetation, snow cover, and land cover based on climate models, incorporating several modern innovative technologies, have not been fully explored.

Connection of the dissertation topic to research plans of the Institution. This dissertation research is aligned with the Resolution No. 458 of the Cabinet of Ministers of the Republic of Uzbekistan, dated August 18, 2022, "On Measures to Further Improve the Activities of the Research Institute for Environmental Protection and Nature Conservation Technologies." Specifically, it contributes to Section 8 of Annex 3, which focuses on developing an automated software product for monitoring ecosystem changes around reservoirs in the Tashkent region using GIS technology (2022–2024).

Research aim. The primary objective of the dissertation is to assess the impact of climate change on vegetation, snow cover, and land cover in the Ugam-Chatkal National Park and provide future forecasts.

Research objectives:

Analyze models for assessing the impact of climate change on vegetation, snow cover, and land cover;

Study climate changes (air temperature, precipitation, and soil temperature) using the Mann-Kendall test and Sen slope, analyzing meteorological station data and satellite imagery for the Bostanlik district and the broader region;

Examine monthly changes in vegetation cover in the Bostanlik district using NDVI, SAVI, the Mann-Kendall test, and Sen slope, as well as their relationship with climatic parameters;

Forecast land use and land cover changes in the Bostanlik district using the CA-Markov model;

Develop scientific recommendations for predicting climate, vegetation, and snow cover for the period 2023–2065.

Research object (study area) focuses on Ugam-Chatkal National Park, located in the Bo‘stonliq district of the Tashkent region.

Research subject. Comprehensive analysis of the impact of climate change on snow cover, vegetation, and land cover in the Bostanlik district using remote sensing and statistical analyses, as well as future forecasting.

Research methods. The research used generally accepted methods in the field of ecology and environmental protection. In particular, geographic information systems (GIS) and remote sensing methods, statistical methods (Mann-Kendall test, Sen's slope and regression analysis), machine learning methods (CA-Markov, Random Forests, ARIMA and Prophet models were used), field research methods, and methods specified in existing regulatory documents.

Scientific novelty of the dissertation includes the following:

Significant decline in cryospheric cover (snow cover detected using NDSI index and ice cover detected using NDSII index) in Bo‘stonliq district from 1991 to 2022 has been identified through remote sensing and statistical analysis ($p_{NDSI} = 0.0026$, $p_{NDSII} = 0.0002$). Future trends for the next 40 years have been forecasted using the Prophet machine learning model;

For the first time, a detailed quantitative assessment of the relationship between cryosphere, vegetation, and climate processes in Bo‘stonliq district from 1991 to 2022 has been conducted using statistical analysis and remote sensing methods.

Statistical correlation between meteorological parameters recorded at Chimgan station (annual precipitation, soil temperature, and air temperature) and ERA5 satellite data has been established;

Using the ARIMA machine learning model, climate data from Chimgan meteorological station and ERA5 satellite data have been used to forecast climate and vegetation changes for the period 2023–2065.

Practical outcomes of the dissertation are the following:

Climate change analysis for the period (1991–2022) using data from the Chimgan meteorological station and ERA5 Copernicus satellite data;

Vegetation cover analysis using NDVI and SAVI indices through remote sensing and non-parametric statistical methods;

Land use and cover change analysis and forecasts for 2035, 2045, 2055, and 2065 using the CA-Markov model;

Cryosphere analysis and future predictions for NDSI, NDVI, air temperature, soil temperature, and precipitation.

Reliability of the research results. The research was conducted using both in situ (on-site) and ex situ (remote sensing) data sources. Landsat imagery with a spatial resolution of 30 meters was utilized, providing relatively high accuracy for analyzing land cover changes. Only atmospherically corrected satellite images were used to ensure data consistency and accuracy. For vegetation analysis and land cover classification, images with a maximum cloud cover of 12% were selected. For cryosphere analysis (snow and ice), stricter criteria were applied,

limiting cloud cover to 8% to ensure precision. The combination of reliable remote sensing and field data validates the study's findings and ensures their dependability.

Scientific and practical significance of the research results. The practical significance of the research lies in the ability to forecast average monthly air temperature, soil temperature, and precipitation with high accuracy using ARIMA models, as confirmed by UzHydromet data. Climate change forecasting contributes to strategies for adapting to and mitigating climate impacts, advancing agricultural development and adaptation plans, sustainable water resource management, stable pasture management, and protecting mountainous regions from floods and landslides.

The scientific significance of the research is reflected in the identification of LULC (Land Use and Land Cover) changes, which enhances the understanding of the historical development of LULC in the region and aids in improving land use policies. Forecasting scenarios for land cover changes help predict how the region may evolve in the near and distant future if current trends persist. This, in turn, assists policymakers in developing strategies to prevent worst-case scenarios.

Implementation of research results. Based on the results obtained on the impact of climate change on land cover in the Ugam-Chatkal National Park and forecasts for the future:

Based on the analysis of meteorological parameters, land cover and soil temperature of the Bostanlyk district of the Tashkent region from 1991 to 2022, the interrelationship of land cover, climate and vegetation was modeled (International Center of Biosaline Agriculture scientific research organization, reference number ICB/0879a dated June 26, 2024). As a result, the possibility of remotely monitoring the impact of climate change on agricultural lands of the Bostanlyk district of the Tashkent region was created;

Based on the results of the research conducted in the Tashkent region, the current state of the UCHNP for the period from 1991 to 2022 (32 years) was analyzed using remote sensing and climate data. Based on the analysis, the Mann-Kendall test and Sen's slope statistical analysis were applied to GAT maps for land use and land cover, and climate data, vegetation and cryosphere indicators (Ministry of Ecology, Environmental Protection and Climate Change of the Republic of Uzbekistan, Reference No. 01/3-8725 dated September 25, 2024). As a result, it not only advances the scientific understanding of the land covering impact of climate change, but also provides practical tools for environmental protection and sustainable use of natural resources.

Approbation of research results. The results of this research were discussed and approved at international, republican conferences and the scientific council of the institute, including 2 international and 2 republican scientific and practical conferences.

Publication of research results. A total of 8 scientific works have been published on the topic of the dissertation, including 8 articles in scientific publications recommended for publication by the Higher Attestation Commission of the Republic of Uzbekistan on the main scientific results of Doctor of

Philosophy (PhD) dissertations, including 4 in foreign journals, 2 in national journals, and 2 at international scientific conferences.

Dissertation structure and volume. The dissertation consists of an introduction, four chapters, a conclusion, references, and appendices. The total volume is 120 pages.

MAIN ESSENCE OF THE DISSERTATION

The **introduction** of the dissertation establishes the relevance and necessity of the chosen topic, outlines the research aim and objectives, and provides information about the research subject and object. It demonstrates the alignment of the conducted research with the priority areas of science and technology development in the republic. The introduction also details the scientific novelty, practical outcomes, theoretical and practical significance of the results, as well as the application of findings in practice, published works, and the structure of the dissertation.

The **first chapter** of the dissertation, titled "**Literature Review and Methodology**", consists of three sections that cover the study area, methodology, and literature review. In the first section, the study area, located in the Bostanlyk district of Tashkent region and encompassing the Ugam-Chatkal National Park, is described in detail from the perspectives of physical geography, hydrology, climate, flora and fauna, and the cryosphere. This section also provides essential information about the national park, its history, and the river system.

In the second section of the dissertation, a comprehensive literature review is conducted within the framework of the research objectives. This section is divided into several subsections, one of which is titled "Climate Change" and includes an in-depth analysis of global, local, and national climate change. It discusses future climate scenarios, current research conducted for the region and the country, the methods and materials used, and existing knowledge gaps. The "Vegetation" subsection provides information on the current state of global biomass and vegetation cover, analysis of vegetation cover using remote sensing and GIS tools, widely used vegetation indices, and their formulas. It also highlights previous studies that have utilized these indices to analyze changes in vegetation cover in the region and the country. The "Cryosphere" subsection examines the components of the cryosphere, their distinctions, and their importance to local ecosystems. Additionally, it presents detailed information on the global and local state of the cryosphere, the impact of climate change on the cryosphere, and the application of remote sensing technologies for cryosphere monitoring. The next subsection, titled "Land Use and Land Cover Changes", analyzes the processes of land use and land cover change, their definitions, and the importance of remote sensing technologies. It also discusses the impact of climate change on land resources and summarizes the results of studies conducted in Central Asia, Uzbekistan, and the Bostanlyk district. In the final part of the third section, titled "Modeling and Forecasting", mathematical modeling tools, methods, and software used for forecasting climate and weather are reviewed. The effectiveness of these models is analyzed based on

studies conducted in various countries. Furthermore, the issue of insufficient tools for forecasting future weather scenarios in Uzbekistan is highlighted.

In the last third "Methodology" section of this chapter comprises several subsections, including Methods and Materials, Analysis of Vegetation Cover Using Remote Sensing, Classification of Land Cover Using Remote Sensing, Spatial Data, Analysis of the Cryosphere in Ugam-Chatkal National Park, Cryosphere Analysis Using Remote Sensing, and Forecast Models. In this section, the methods, materials, data, software, and mathematical tools used for the dissertation and each research objective are described in detail. Non-parametric statistical analysis tools, such as the Mann-Kendall test and Sen's slope, are widely applied to analyze climate data, vegetation indices, and cryosphere indices. These tools, while widely used by researchers and international organizations in various countries, are unfortunately unfamiliar to many researchers in Uzbekistan. Nevertheless, their robustness and simplicity distinguish them and make them highly valuable for research.

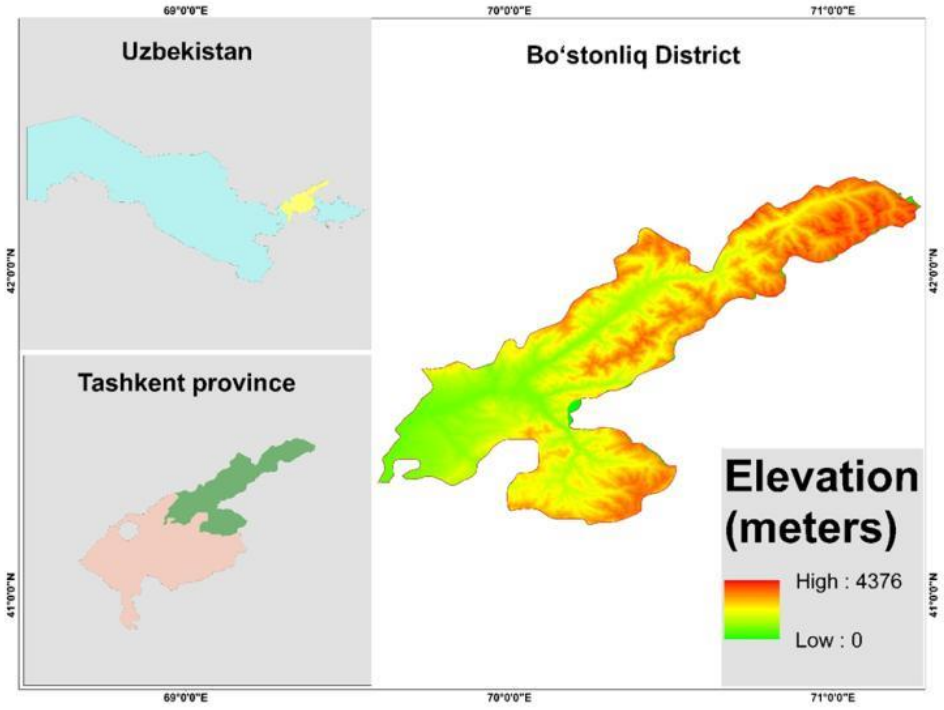

Figure 1. Research Object and Location of Observation Stations.

$$S = \sum_{\{k=1\}}^{n} \sum_{k=j+1}^{n} sgn(y_j - y_k) \quad (1)$$

Here: n is the number of common elements, k and j are indices, where values from j to k are taken; sgn is the "signum" function, which determines the sign (positive, negative, or zero) of the difference $y_j - y_k$.

Their parametric statistical tools, such as Pearson's correlation and regression analysis (which were also used in the dissertation), compared to non-parametric methods, are ideally suited for non-normative data, identify monotonic trends, and are easy to interpret. Pearson's correlation coefficient, often referred to as "R," is a

statistical measure that quantifies the strength and direction of the linear relationship between two variables. It was used to measure the relationship between climatic, cryospheric, and vegetation variables, as well as to determine trends in annual changes in air temperature, soil temperature, and precipitation.

$$\boldsymbol{Sen's\ slope = Median\left\{\frac{x_{j-}\,x_i}{j-i} : i < j\right\}} \qquad \textbf{(2)}$$

Here: Sen's slope: This is Sen's slope coefficient, which is used to estimate the trend in time series; Median: This means finding the median value of all slopes calculated in the formula; xj−xi: This indicates the amount of change between the values, where the value at index jj is subtracted from the value at index ii; j−i: This indicates the time or other variable between the two indices; i<j: This condition indicates that the i-index must be less than the j-index.

Several diverse and well-established indices were used to analyze vegetation cover and the cryosphere, including the Normalized Difference Vegetation Index (NDVI), the Soil-Adjusted Vegetation Index (SAVI), the Normalized Difference Snow Index (NDSI), the Normalized Difference Glacier Index (NDGI), and the Normalized Difference Snow and Ice Index (NDSII). These indices were applied to analyze data using Landsat satellite imagery for the period from 1991 to 2022.

$$\boldsymbol{NDVI = \frac{NIR - RED}{NIR + RED}}$$

$$\boldsymbol{SAVI = \frac{(NIR - RED) * (1 + L)}{NIR + RED + L}}$$

$$\boldsymbol{NDSI = \frac{(GREEN-SWIR)}{(GREEN+SWIR)}} \qquad \textbf{(3)}$$

$$\boldsymbol{NDGI = \frac{(Green - RED)}{(Green + RED)}}$$

$$\boldsymbol{NDSII = \frac{(RED - SWIR)}{(RED + SWIR)}}$$

Here: NIR – Near-Infrared range; RED – Red wavelength (important for determining plant absorption and their condition); Green – Green wavelength; SWIR – Shortwave Infrared range (Shortwave Infrared).

In the **second chapter** of the dissertation, titled "**Analysis of Climate Change in the Ugam-Chatkal National Park in 1991–2022 Using the Mann-Kendall Test and Sen's Slope**" the study focuses on analyzing climate changes in the Ugam-Chatkal National Park during the 1991-2022 period. The research covers the period from 1991 to 2022 and examines climate parameters such as the average monthly air temperature, average monthly soil temperature, and monthly

precipitation levels. Non-parametric statistical methods, namely the Mann-Kendall test and Sen's slope, were used in the study, utilizing data from the Chimgan meteorological station and Copernicus ERA5 satellite measurements. The Mann-Kendall test identifies trends, while Sen's slope quantifies the magnitude of these trends.

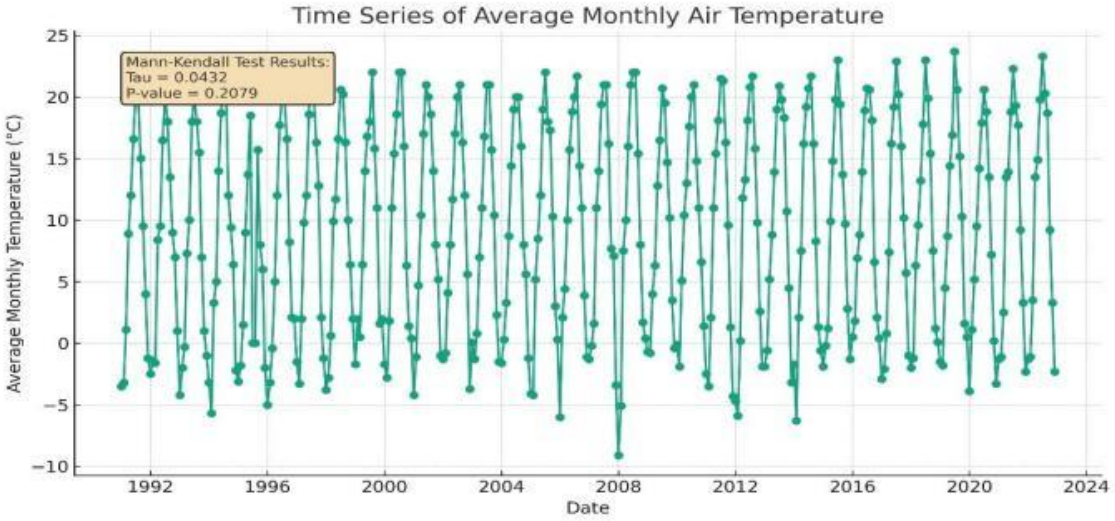

Figure 2. Graph of Average Monthly Air Temperature for Bostanlik from 1991 to 2022 (Data from Chimgan Meteorological Station).

The results indicate that there are no statistically significant trends in air temperature or precipitation. However, the Bostanlik district shows an almost significant trend of increasing soil temperature, with a p-value of 0.07, suggesting a warming tendency. The high correlation between ground-based data and remote sensing data confirms the reliability of the measurements, although discrepancies in precipitation trends highlight challenges in collecting accurate data across different terrains.

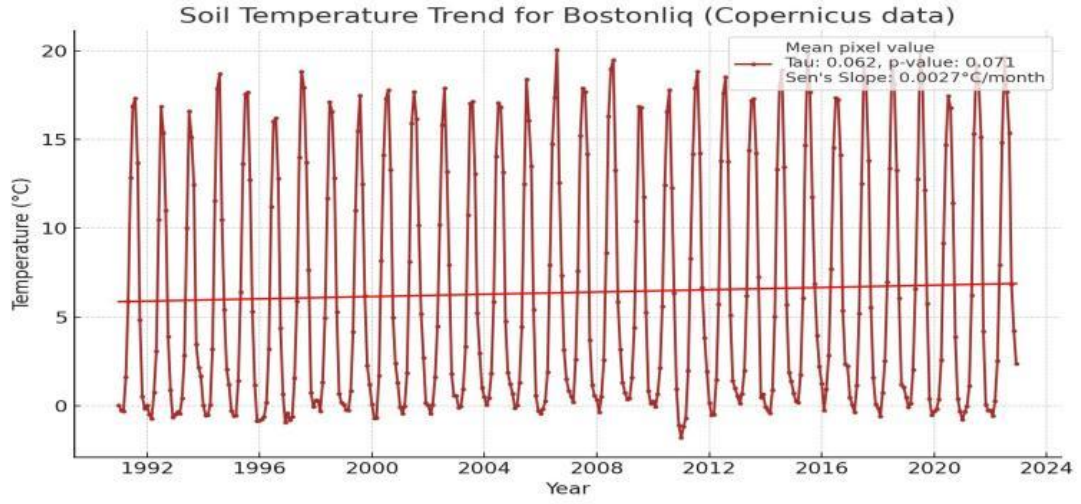

Figure 3. Soil Temperature Analysis for the Bostanlik District Based on Copernicus Climate Data Using the Mann-Kendall Test and Sen's Slope.

This chapter emphasizes the importance of continuous climate monitoring to better understand subtle changes in the region's climate. The absence of significant changes in air temperature and precipitation may either indicate natural fluctuations or the need for more precise data. Study limitations include the accuracy of meteorological sensors and the scope of the assessment, underscoring the need to improve climate monitoring infrastructure. The conclusion is that, although no significant changes were detected, observed trends in soil temperature may signal early signs of climate change impact, necessitating further research and monitoring.

In the **third chapter** of the dissertation, titled "**Analysis of the impact of climate change on vegetation cover using remote sensing and statistical tools in 1991-2022**" the study examines changes in vegetation cover in the Ugam-Chatkal National Park from 1991 to 2022. Using NDVI and SAVI indices obtained from Landsat 5, 7, and 8 satellite images, this chapter studies the relationship between vegetation indices and climate variables, such as soil and air temperature and precipitation, through correlation analysis (Figures 3 and 4). The analysis revealed a very strong positive correlation between vegetation indices and soil and air temperatures, with soil temperature having a more significant impact. Conversely, a moderate negative correlation was identified between vegetation indices and precipitation levels, indicating that vegetation develops most actively during periods of low precipitation. The analysis using the Mann-Kendall test and Sen's slope demonstrated a statistically significant positive trend for both NDVI and SAVI indices during the 1991-2022 period, indicating an increase in vegetation cover.

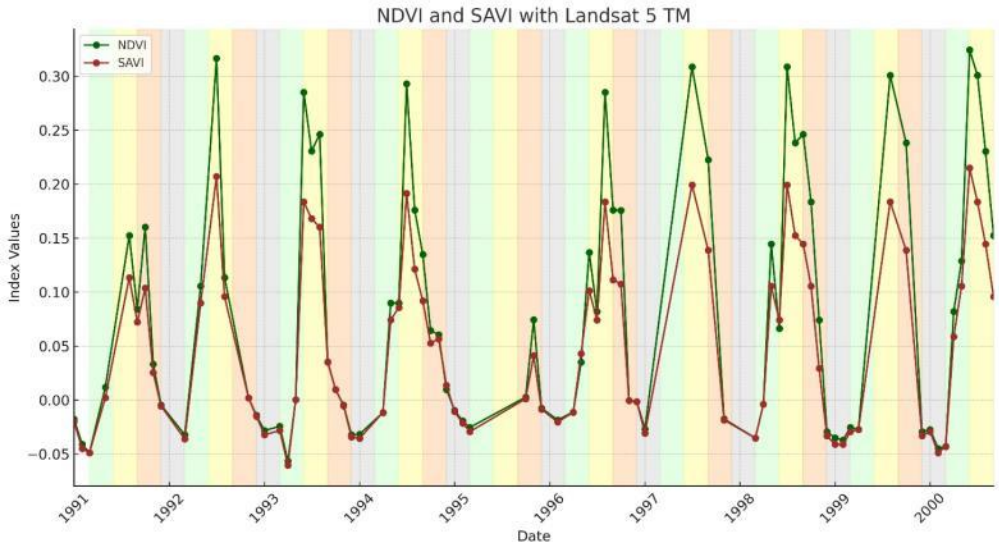

Figure 4. Monthly Average NDVI and SAVI for the Study Area (1991–2000).

The chapter concludes that vegetation cover in the Boston area has increased significantly, largely due to increased soil and air temperatures. This positive trend in vegetation cover is explained by increased photosynthetic activity due to warmer conditions. However, the reliability of these findings is limited by the number of images analyzed, which suggests that more accurate results could be obtained by including more data. The study highlights the important role of temperature in vegetation dynamics and highlights the need for continued monitoring and larger data sets to confirm these trends (Figures 4, 5, and 6).

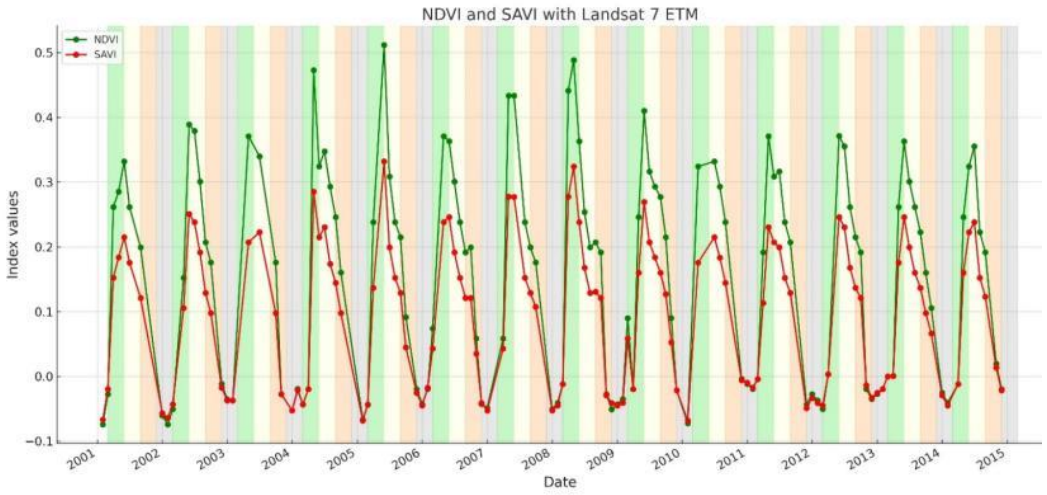

Figure 5. Monthly Average NDVI and SAVI for the Study Area (2001–2015)

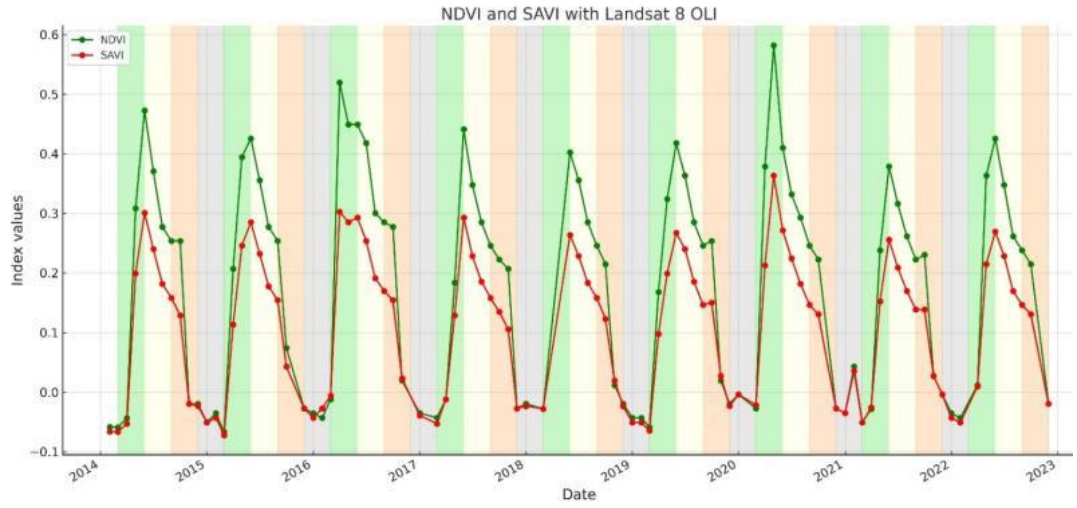

Figure 6. Monthly Average NDVI and SAVI for the Study Area (2014–2022).

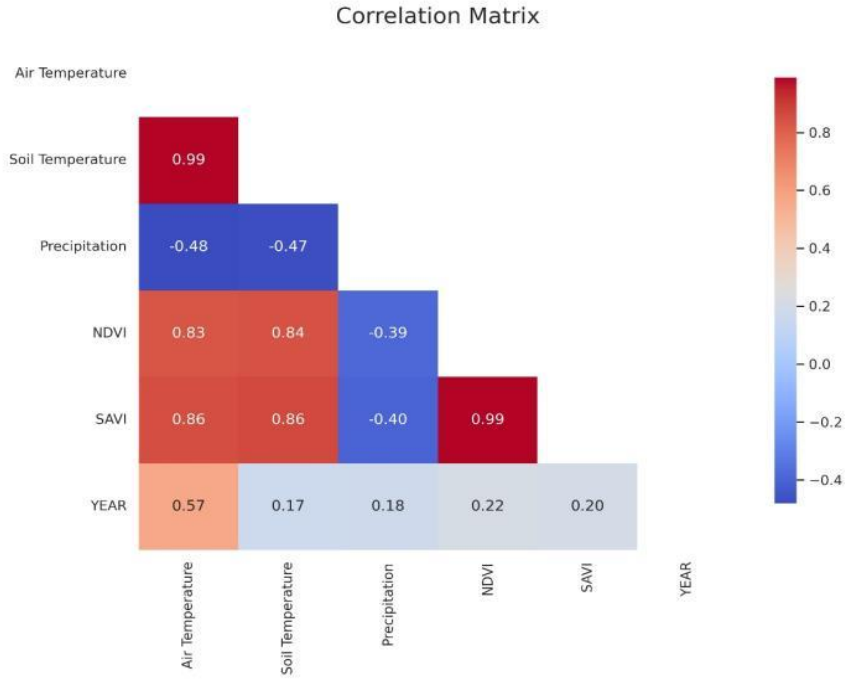

Figure 7. Correlation Matrix Between Climate Parameters and Average Vegetation Indices.

The analysis showed a very strong positive correlation between vegetation indices and soil and air temperatures, with soil temperature having a stronger effect. In contrast, a moderately strong negative correlation was found between vegetation indices and precipitation, indicating that vegetation is at its highest during periods of low precipitation. The Mann-Kendall test and Sen's slope analysis showed a statistically significant positive trend in both NDVI and SAVI indices over the period 1991-2022, indicating an increase in vegetation cover (Figure 7).

In the **fourth chapter**, titled "**Land Use and Land Cover Change in the Ugam-Chatkal National Park in 1991–2022 and Forecasts Using Remote Sensing**" the study examines changes in land use and land cover (LULC) in the Ugam-Chatkal National Park during the 1991-2022 period from 1991 to 2022 using Landsat imagery. The research categorizes the Bostanlik district into eight classes: open lands, water bodies, agricultural lands, mountainous areas, forest cover, pastures, glaciers, and urban areas. The classification was performed using high-resolution imagery processed through the Google Earth Engine (GEE) platform and achieved an accuracy of 86% to 88%.

The research results indicate that the snow and glacier cover, which amounted to 2,015 km² in 1993, had decreased to 1,400 km² by 2022 due to global climate change. Forest cover and urban areas increased, while the areas of pastures and open lands fluctuated. Future land use and land cover (LULC) predictions using the CA-Markov model in the TerrSet software were analyzed under three scenarios: complex (average), mild (optimistic), and adverse (business-as-usual). The complex and mild scenarios produce similar forecasts, whereas the adverse scenario predicts rapid expansion of urbanization and agricultural lands.

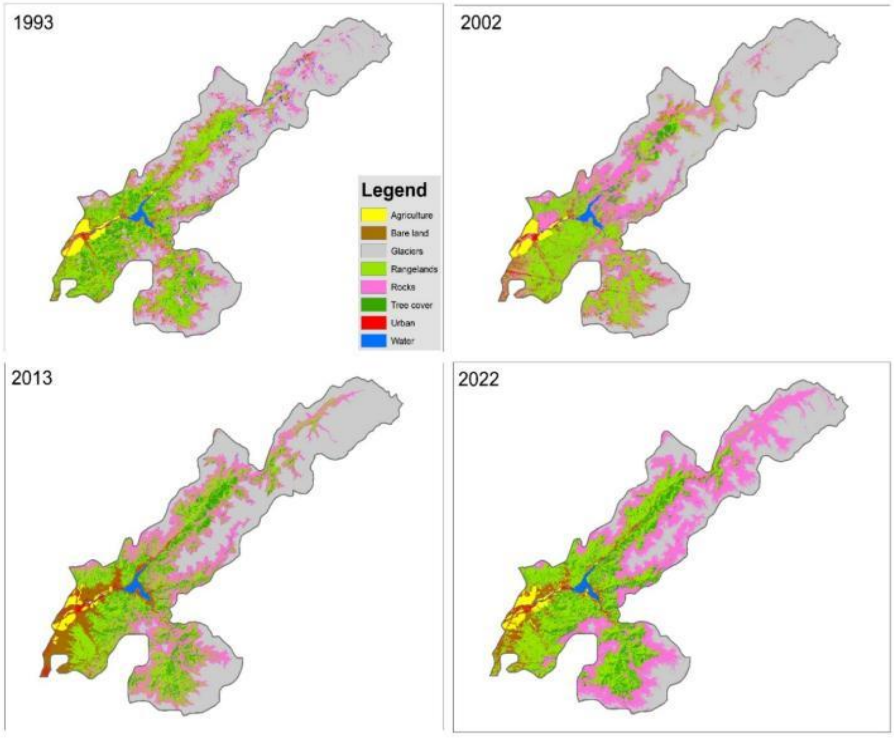

Figure 8. Changes in Land Use and Land Cover in Bostanlik District (Ugam-Chatkal National Park) During the 1993-2022 Period.

This chapter demonstrates that ongoing climate change will continue to impact land cover, highlighting the necessity of developing sustainable management strategies. The obtained data provide a deep understanding of past changes and future projections, aiding policymakers in formulating informed conservation strategies and mitigating negative consequences. The study emphasizes the importance of integrating remote sensing data with advanced machine learning methods.

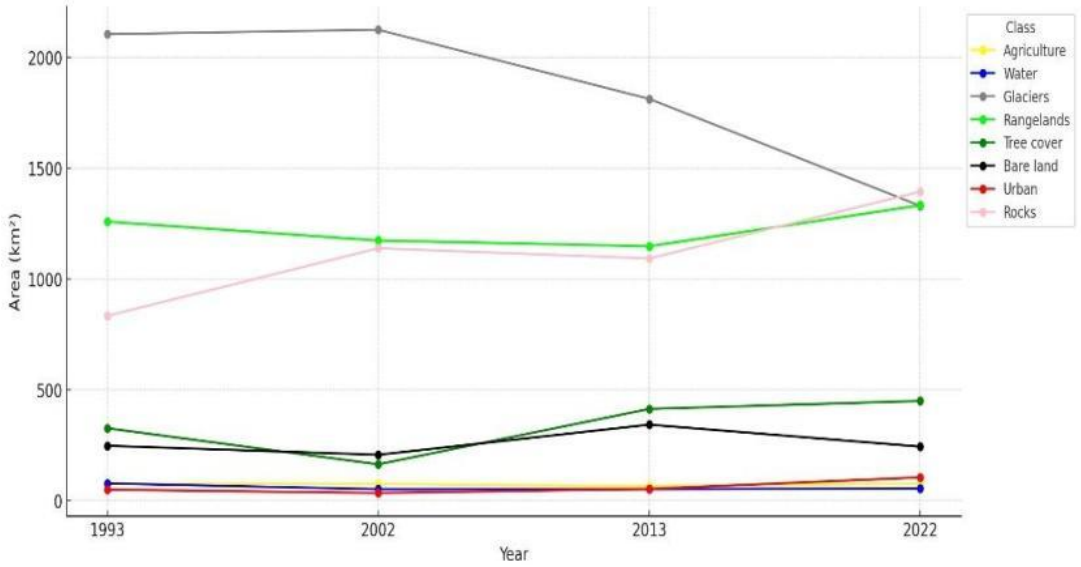

Figure 9. Changes in Land Use and Land Cover in Bostanlik District (Ugam-Chatkal National Park) During the Period (1993–2022).

In the **fifth chapter**, titled "**Analysis of the Impact of Climate Change on Cryosphere Changes Using Remote Sensing in 1991–2022**" the study focuses on assessing changes in snow and glacier cover in the Ugam-Chatkal National Park over the period from 1991 to 2022. Using remote sensing data and indices such as NDSI, NDGI, and NDSII, this chapter employs the Mann-Kendall test and Sen's slope to identify change trends.

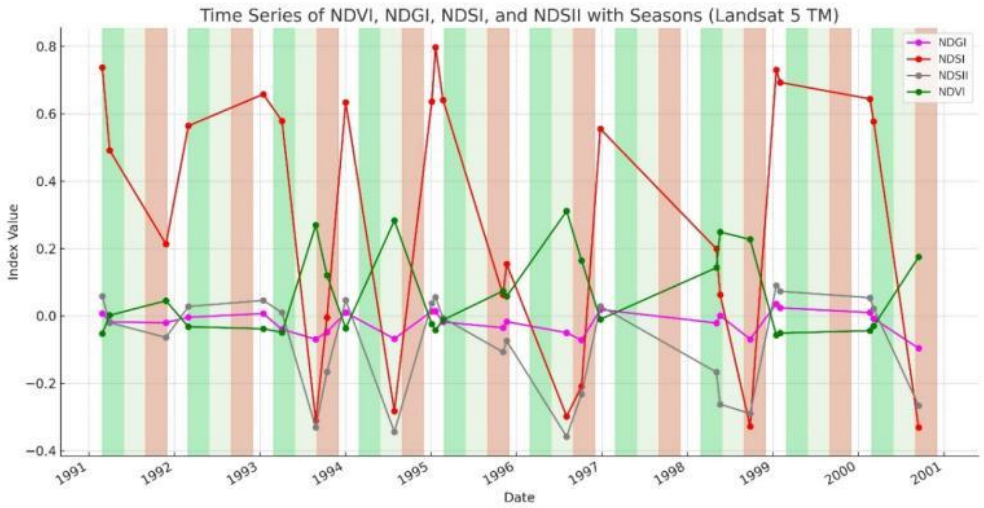

Figure 10. Cryosphere Time Series Changes in Bostanlik disrict (Ugam-Chatkal National Park) Using Landsat 5 Data (1991–2000).

The research results indicate that snow cover, as measured by NDSI and NDSII indices, has significantly decreased, with statistically significant downward trends. Glacier cover (NDGI) showed minor changes without long-term trends. The negative correlation between cryosphere indices and soil temperature suggests that rising temperatures lead to reductions in snow and glacier cover. The study emphasizes the necessity of continuous monitoring to manage the negative impacts of climate change on the cryosphere, which is critical for water resource management and maintaining ecological balance.

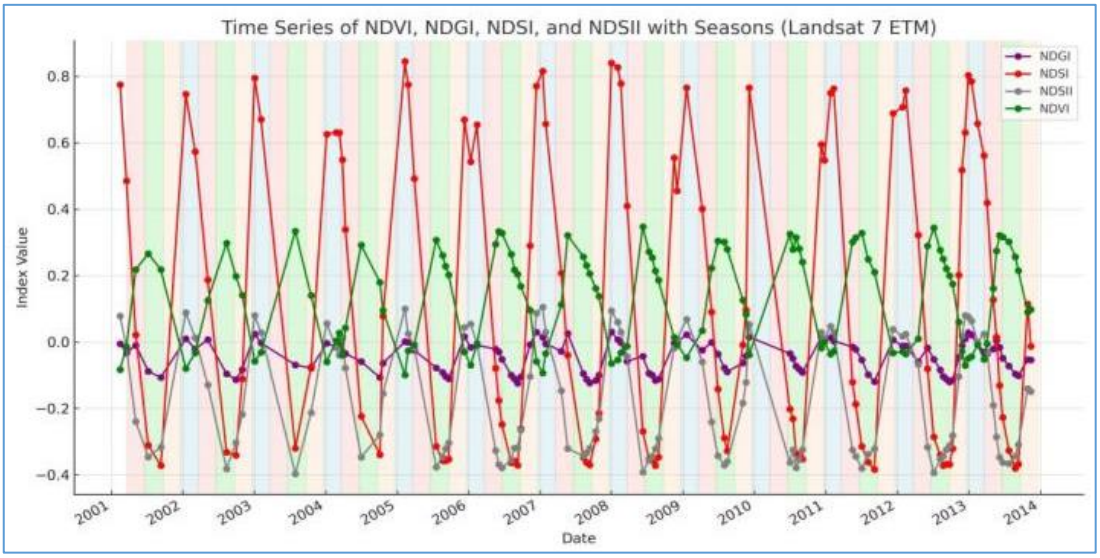

Figure 11. Cryosphere Time Series Analysis in Bostanlik District(Ugam-Chatkal National Park) Using Landsat 7 ETM Data (2001–2014).

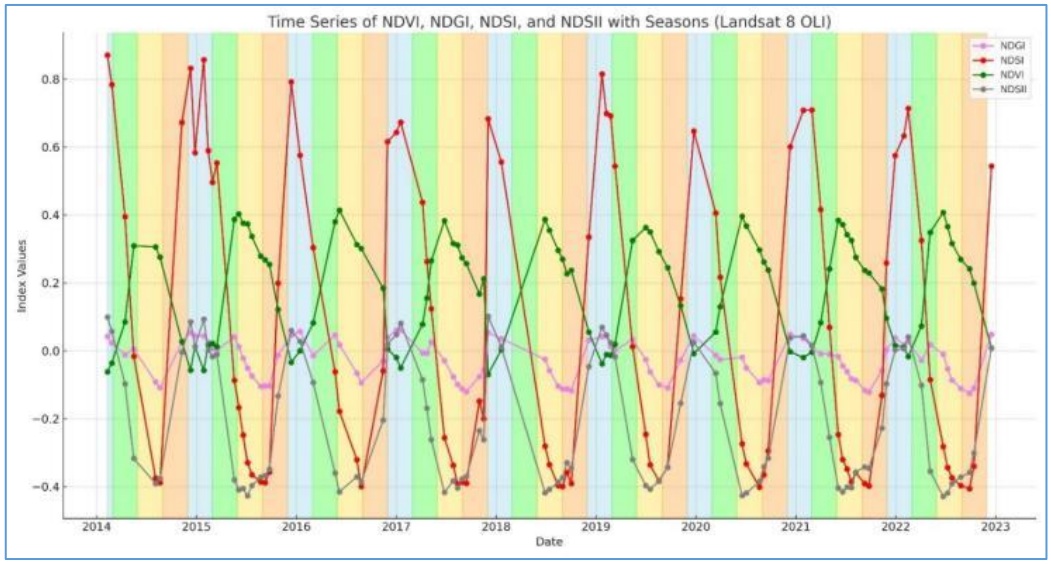

Figure 12. Cryosphere Time Series Analysis in Bostanlik District(Ugam-Chatkal National Park) Using Landsat 8 OLI Data (2014–2022).

The conclusions emphasize that in response to the reduction of cryospheric areas, strategic interventions must be implemented to conserve water resources and ensure ecological stability. The study provides crucial insights into the relationship between climatic variables and cryosphere dynamics, highlighting the importance of adaptive management strategies to mitigate the negative impacts of climate change.

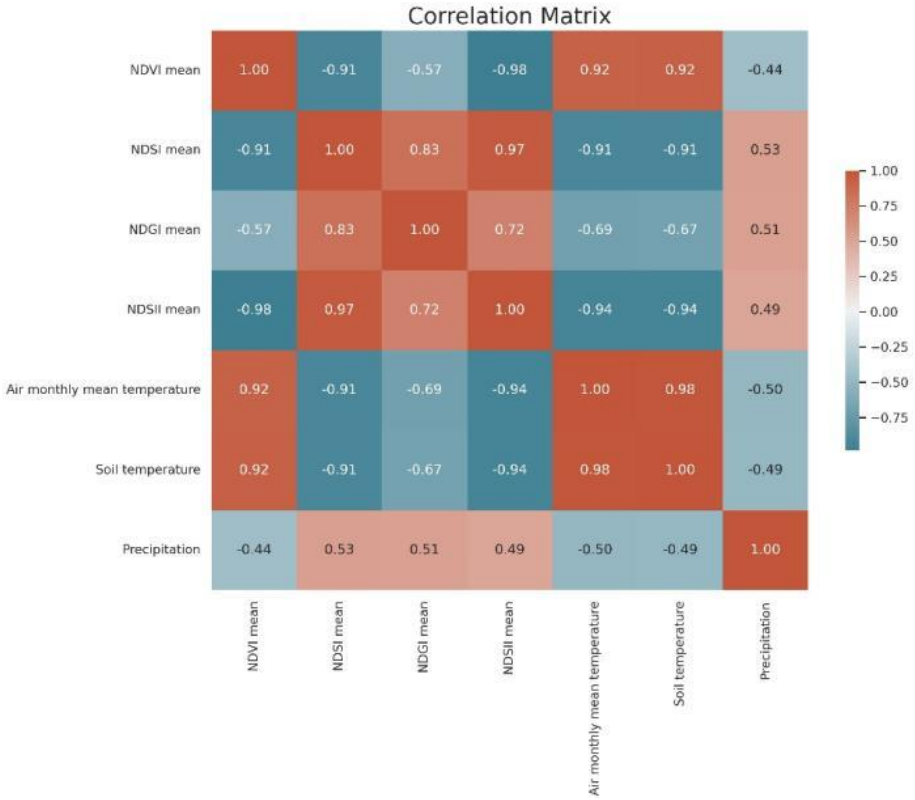

Figure 13. Correlation Matrix Between Climate, Cryosphere, and Average Vegetation Indices.

In the **six chapter**, titled **"Forecasts for Vegetation, Climate, and Snow Cover Using ARIMA and Prophet Models"** ARIMA is used to forecast future trends in monthly soil temperature, air temperature, precipitation, NDVI, and NDSI for the period 2023 to 2065. The Prophet model is also employed. The SARIMA model demonstrated good performance in validating air and soil temperatures but yielded only moderate results for precipitation due to its high variability.

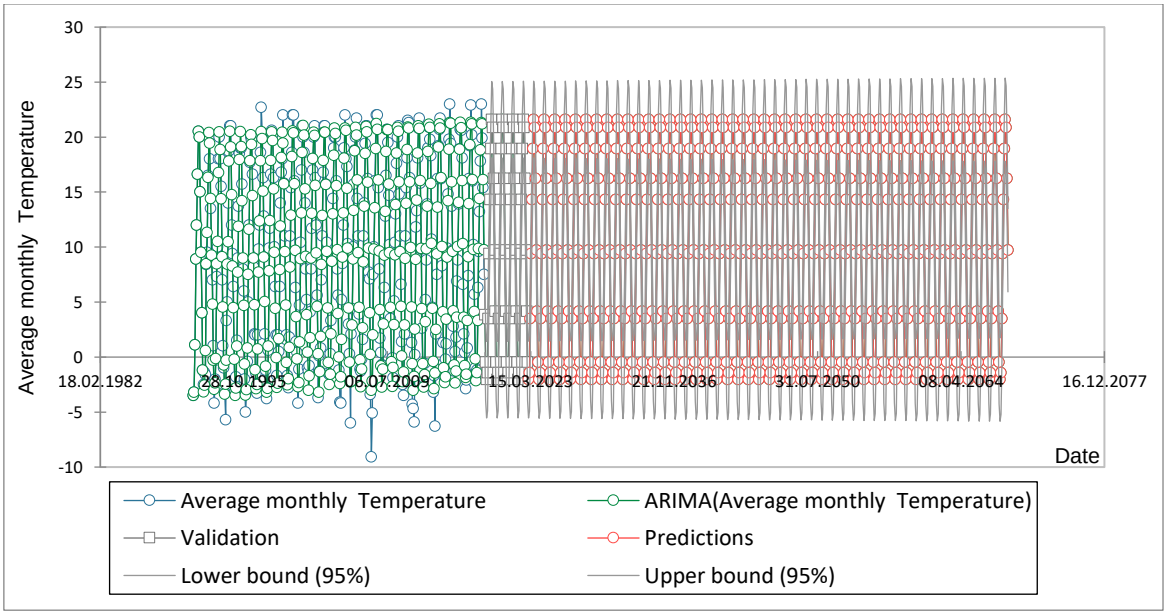

Figure 14. Air Temperature Forecast for the Next 40 Years Based on Chimgan Data.

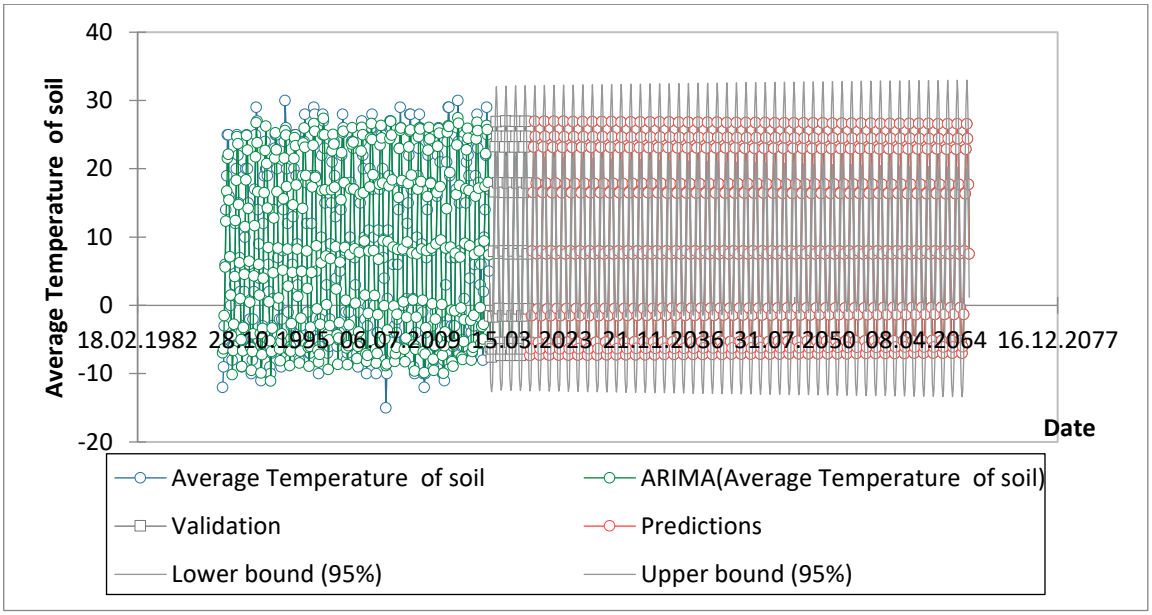

Figure 15. Soil Temperature Forecast Based on Chimgan Data.

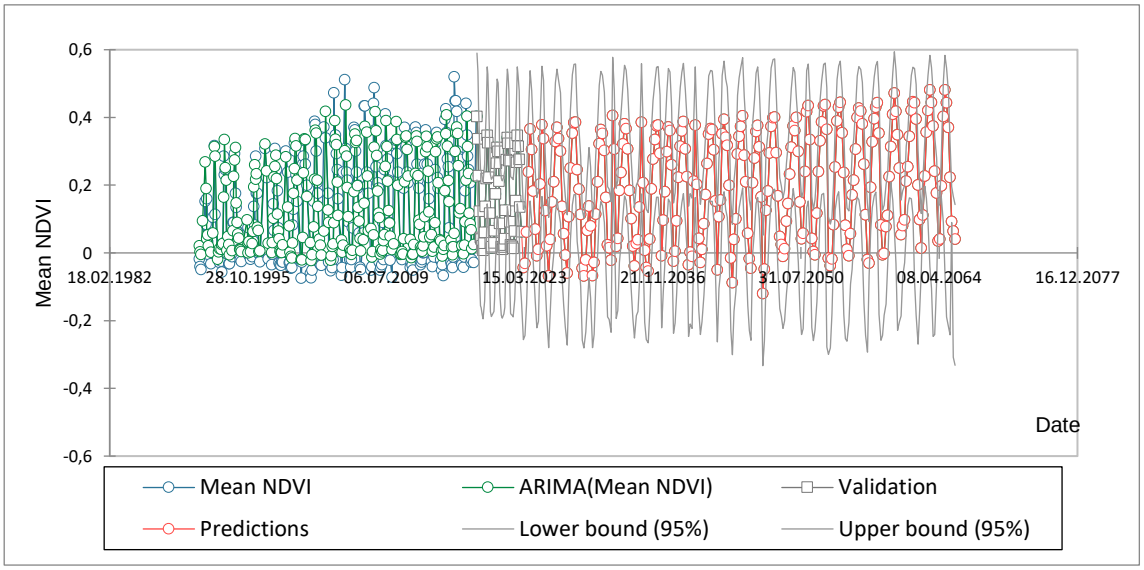

Figure 16. Future NDVI Forecast Using ARIMA Model.

The forecasts do not indicate statistically significant trends in climate parameters based on Chimgan data; however, ERA5 data suggest a slight increase in air temperature and a decrease in precipitation. Soil temperature forecasts for the Bostanlik region show an almost statistically significant upward trend, which could impact snow cover and contribute to ground warming. It is predicted that NDVI will increase as snow cover decreases and is replaced by vegetation. Due to the lack of NDSI data, the Prophet model predicts a significant reduction in snow cover, emphasizing the need for flexibility in water resource management strategies.

CONCLUSIONS

Based on the research conducted within the framework of the PhD dissertation titled "Assessment of the Impact of Climate Change on Land Cover in the Ugam-Chatkal National Park and Future Projections," the following conclusions are presented:

1. A comprehensive climate analysis was conducted using field data from the Chimgan meteorological station and ERA5 satellite data for the years 1991–2022. The compatibility between satellite and field data was verified, showing high correlations (0.97–0.98). Climate parameters such as air temperature, soil temperature, and precipitation were studied for the Chimgan station, Bustonliq district (ERA5), and a large microclimate area covering 30,000 square kilometers (ERA5). The results indicated a decrease in snowfall (tau = -0.016, p = 0.048), an increase in soil temperature (tau = 0.065; p = 0.07), and relative stability in precipitation (tau = -0.044, p = 0.19).
2. Vegetation analysis for the studied area during 1991–2022 was performed using Landsat imagery and vegetation indices (NDVI, SAVI) alongside non-parametric tools (Mann-Kendall test and Sen's slopes). Both indices revealed statistically significant upward trends in vegetation growth (tau = 0.12, p = 0.0019). The SAVI index showed a stronger correlation with soil and air temperatures compared to NDVI (R = 0.86). Both indices demonstrated a negative correlation with precipitation (R = -0.47).
3. A comprehensive analysis of land use and land cover changes in the study area revealed that the cryosphere (snow cover and glaciers) decreased by 30% between 1993 and 2022. Additionally, tree cover showed a significant increase (+25%), while rock surfaces (+34%) and residential areas (+30%) also expanded. Future projections using the CA-Markov model indicated a continued reduction in glaciers, with rock and vegetation cover replacing them.
4. Cryosphere analysis was conducted using remote sensing indices (NDSI, NDGI, NDSII) and revealed a decrease in snow and ice cover in the study area (tau = -0.13, p = 0.0026). Glacier cover, however, remained stable without significant changes (tau = 0.026, p = 0.54). NDSI and NDSII showed a strong negative correlation with soil temperature (-0.91 and -0.94) and a moderate positive correlation with precipitation (0.53 and 0.49). NDGI (glacier index) had a smaller correlation with soil and air temperatures (-0.69 and -0.67) but showed similar positive correlations with precipitation (0.51). All three cryosphere indices had negative correlations with NDVI, with NDSI and NDSII showing significantly stronger negative correlations (R = -0.97).
5. Future projections for NDVI, cryosphere indices (NDSII), precipitation, air temperature, and soil temperature were conducted using ARIMA and Prophet models, yielding the following results: NDSII (snow and ice index) is expected to continue decreasing over the next 40 years (tau = -0.15, p = 0.02), while NDVI will continue increasing, indicating further replacement of the study area by vegetation cover (tau = 0.11, p = 0.04). Soil temperature (ERA5) will gradually rise across the region (tau = 0.09, p = 0.06), while air temperature will show a slight decrease, though the results are not statistically significant (tau = 0.04, p = 0.1). Precipitation is expected to remain stable over the next 40 years.
6. In conclusion this study area show, specifically on the patterns of annual precipitation, namely the decline of snowfalls and increase of rainfalls, which results in decline of snow cover and its replacement with vegetation.

НАУЧНЫЙ СОВЕТ PhD.18/30.T.153.01 ПО ПРИСУЖДЕНИЮ УЧЁНЫХ СТЕПЕНЕЙ ПРИ НАУЧНО - ИССЛЕДОВАТЕЛЬСКОМ ИНСТИТУТЕ ОКРУЖАЮЩЕЙ СРЕДЫ И ПРИРОДООХРАННЫХ ТЕХНОЛОГИЙ

НАУЧНО-ИССЛЕДОВАТЕЛЬСКИЙ ИНСТИТУТ ОКРУЖАЮЩЕЙ СРЕДЫ И ПРИРОДООХРАННЫХ ТЕХНОЛОГИЙ

АЛИХАНОВ БАХИР БОРИЕВИЧ

ОЦЕНКА ВЛИЯНИЯ КЛИМАТИЧЕСКИХ ИЗМЕНЕНИЙ НА ЗЕМЕЛЬНЫЙ ПОКРОВ УГАМ-ЧАТКАЛЬСКОГО НАЦИОНАЛЬНОГО ПАРКА И ПРОГНОЗИРОВАНИЕ НА БУДУЩЕЕ

11.00.05-Охрана окружающей среды и рациональное использование природных ресурсов

АВТОРЕФЕРАТ ДИССЕРТАЦИИ ДОКТОРА ФИЛОСОФИИ (PhD) ПО ТЕХНИЧЕСКИМ НАУКАМ

ТАШКЕНТ – 2025

Тема диссертации доктора философии (PhD) по техническим наукам зарегистрирована в Высшей аттестационной комиссии при Министерство высшего образования, науки и инноваций Республики Узбекистан под номером № B2024.3.PhD/T180

Диссертация выполнена в НИИ окружающей среды и природоохранных технологий.

Автореферат диссертации на трех языках (узбекский, русский, английский (резюме)) веб-страница института (ecoilm.uz, uznature.uz) и на информационном образовательном портале “Ziyonet" (www.ziyonet.uz) размещены.

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Ведущая организация:	**Национальный Университет Узбекистана имени Мирзо Улугбека**

Защита диссертации состоится «___ __» _____ 202_ г. _____ часов на заседании Ученого совета PhD.18/30.11.2022.T.153.0 при Научно-исследовательский институт окружающей среды и природоохранных технологий по адресу: 100043, город Ташкент, Чиланзарский район, проспект Бунёдкор, дом 7а. (тел.: (71)277-69-83; факс.: (71)277-89-22; эл. почта.: eco_nii@uznature.uz).

С диссертацией можно ознакомиться в Информационно-ресурсном центре Научно-исследовательского института окружающей среды и природоохранных технологий (регистрационный номер ___). (Адрес: 100043, город Ташкент, Чиланзарский район, проспект Бунёдкор, дом 7а. (тел.: (71) 277-69-83; факс.: (71) 277-89-22;, эл. почта). : ecoilm.uz).

Автореферат диссертации разослан « ___» _____ 202_ года.

(протокол рассылки № ____ « ___» _____ 202_г.).

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ВВЕДЕНИЕ (реферат докторской диссертации)

Актуальность и значимость темы диссертации обусловлены глобальными изменениями климата, которые приводят к изменениям климатических условий, вызванным как природными системами, так и антропогенными выбросами парниковых газов. Особое внимание уделяется оценке воздействия на региональном уровне и использованию региональных климатических моделей в процессе принятия решений для поддержки адаптации к изменениям климата. В настоящее время, в условиях изменения климата, особую важность приобретают вопросы землепользования и земного покрова, эрозионных процессов в речных бассейнах, анализа динамики уровня воды и их долгосрочного прогнозирования в рамках охраны окружающей среды, непосредственно связанных с водными ресурсами речных бассейнов.

Цель исследования. Оценка воздействия изменения климата на растительность, снежный покров и земной покров в Угам-Чаткальском национальном парке, а также прогнозирование этих изменений в будущем.

Объект исследования. Анализ влияния изменения климата на земной покров Угам-Чаткальского национального парка в период с 1991 по 2022 годы и прогноз на будущее.

Научная новизна исследования заключается в следующем:

- Установлено, что криосферный покров Бостанлыкского района, а именно снежный покров (определённый с помощью индекса NDSI) и ледяной покров (определённый с помощью индекса NDSII), сокращался в период с 1991 по 2022 годы. Это было подтверждено с высокой степенью достоверности на основе дистанционного зондирования и статистического анализа (pndsi = 0.0026, pndsii = 0.0002). Прогноз изменения тенденций на следующие 40 лет выполнен с использованием модели машинного обучения Prophet.
- Впервые проведена количественная оценка взаимосвязи между криосферой, растительным покровом и климатическими процессами в Бостанлыкском районе за период 1991–2022 годов с применением глубокого статистического анализа и методов дистанционного зондирования. Оценено влияние динамики криосферы и растительного покрова на изменения климата.
- Подтверждена статистическая корреляционная связь между климатическими параметрами, собранными на метеостанции Чимган (годовое количество осадков, температура почвы и воздуха), и аналогичными параметрами, предоставленными спутниковыми данными ERA5.
- С использованием математической модели машинного обучения ARIMA, на основе климатических данных, полученных с метеостанции Чимган, и спутниковых данных ERA5 выполнен прогноз изменений климата и растительного покрова на период 2023–2065 годов.

Внедрение результатов исследований. На основании полученных результатов по влиянию изменения климата на почвенный покров в Угам-Чаткальском национальном парке и прогнозов на перспективу:

На основе анализа метеорологических параметров, почвенного покрова и температуры почвы Бостанлыкского района Ташкентской области за период с 1991 по 2022 годы смоделирована взаимосвязь почвенного покрова, климата и растительности (Международный центр биосолевого земледелия научно-исследовательская организация, номер ссылки ICB/0879a от 26 июня 2024 года). В результате создана возможность дистанционного мониторинга влияния изменения климата на сельскохозяйственные угодья Бостанлыкского района Ташкентской области;

На основании результатов исследований, проведенных в Ташкентской области, с использованием данных дистанционного зондирования и климатических данных проанализировано современное состояние УЧНП за период с 1991 по 2022 год (32 года). На основе анализа был применен тест Манна-Кендалла и статистический анализ наклона Сена к картам GAT для землепользования и растительного покрова, а также климатических данных, показателей растительности и криосферы (Министерство экологии, охраны окружающей среды и изменения климата Республики Узбекистан, ссылка № 01/3-8725 от 25 сентября 2024 г.). В результате это не только способствует научному пониманию воздействия изменения климата на земной покров, но и предоставляет практические инструменты для охраны окружающей среды и устойчивого использования природных ресурсов.

Апробация результатов исследования: результаты данного исследования были обсуждены и одобрены на 2 международных и 2 национальных научно-практических конференциях.

Публикация результатов исследования. По теме диссертации опубликовано 5 научных работ, из которых 2 статьи опубликованы в научных изданиях, рекомендованных для публикации основных научных результатов диссертаций Высшей аттестационной комиссией Республики Узбекистан, и 3 статьи опубликованы в международных журналах, индексируемых в базе данных SCOPUS.

E’LON QILINGAN ISHLAR RO‘YXATI
СПИСОК ОПУБЛИКОВАННЫХ РАБОТ
LIST OF PUBLISHED WORKS

I bo‘lim (I часть; I part)

1. Alikhanov B., Pulatov B., Samiev L., Analysis of climate change in Ugam Chatkal National Park, bostanliq district, during the post-soviet period using mann-kendall test and sen's slope statistical analysis. Ekologiya xabarnomasi Jurnali. №1/2024. 2024. (11.00.00; №03)
2. Pulatov B, Alikhanov B, Samiev L., Statistical analysis of vegetation indices of the Ugam Chatkal National Park, bostanliq district, during the post-soviet period (1991 -2022) using mann-kendall test and sen's slope. Ekologiya xabarnomasi Jurnali. №2/2024.2024. (11.00.00; №03)
3. Alikhanov B, Pulatov B, Samiev L., Vegetation Cover Change in Ugam Chatkal National Park, Uzbekistan, in Relation to Climate Variables During the Post-Soviet Period (1991-2022). Forum Geografi. Vol. 38(No. 1). DOI: 10.23917/forgeo. v38i1.3824. 2024. (www.scopus.com)
4. Alikhanov B, Pulatov B, Samiev L. The Detection of Past and Future Land Use and Land Cover Change in Ugam Chatkal National Park, Uzbekistan, Using CA-Markov and Random Forest Machine Learning Algorithms. Forum Geografi.Vol. 38(2):121-137. DOI: 10.23917/forgeo.v38i2.4221. 2024. (www.scopus.com)
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6. Attia, A., Qureshi, A.S., Kane, A.M., Datta, A., Samasse, K. Selection of Potential Sites for Promoting Small-Scale Irrigation across Mali Using Remote Sensing and GIS *Sustainability (Switzerland)*, 2022, 14(19), 12040. (www.scopus.com)

II bo‘lim (II часть; II part)

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9. Rustami, D., Alikhanov, B. Water-related ecosystem services and methods for evaluating them by stakeholders' perceptions: a review article. *«Қишлоқ ва сув хўжалигининг замонавий муаммолари» мавзусидаги анъанавий XVIII – ёш олимлар, магистрантлар ва иқтидорли талабаларнинг илмий-амалий анжумани*, Тошкент, 2019 йил, 28-29 март.

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