TARIMSAL ÇEVRE KİRLİLİĞİ

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ÖNSÖZ

Tarım, insanlığın varoluşundan bu yana yaşamın temelini oluşturan en stratejik faaliyet alanlarından biridir. Beslenmenin ötesinde ekonomik kalkınma, kırsal istihdam, toplumsal refah ve ekosistem hizmetlerinin devamlılığı açısından da kritik bir rol üstlenmektedir. Artan dünya nüfusu, kentleşme, değişen tüketim alışkanlıkları ve iklim değişikliğinin etkileri, tarımsal üretimin, miktar ve kalite açısından sürdürülebilirliğini zorunlu kılmaktadır. Bu süreçte doğal kaynaklar üzerindeki baskı giderek artmakta; özellikle toprak, su ve biyolojik çeşitlilik ciddi tehditlerle karşı karşıya kalmaktadır. Üretimde verim artışı sağlama amacıyla kullanılan kimyasal gübreler, pestisitler, yoğun sulama uygulamaları ve mekanizasyon; kısa vadede üretim artışı sağlasa da uzun vadede çevresel dengeyi bozabilmektedir. Bilinçsiz ve aşırı girdi kullanımı, toprakta tuzluluk ve asitleşme sorunlarına, organik madde kaybına ve toprak biyotasının zayıflamasına yol açabilmektedir. Benzer şekilde, yüzey ve yeraltı sularına taşınan azot ve fosfor bileşikleri ötrofikasyon riskini artırmaktadır. Bununla birlikte pestisit kalıntıları ekosistem ve insan sağlığı açısından tehdit oluşturmaktadır.

Tarımsal faaliyetlerden kaynaklanan sera gazı emisyonları ise iklim değişikliğini hızlandırarak tarımın kendisini de olumsuz etkileyen bir geri besleme mekanizması yaratmaktadır. Bu çevresel baskılar yalnızca üretim girdilerinin yoğun kullanımıyla sınırlı kalmamakta, arazi kullanım kararları ve yönetim uygulamalarıyla daha da karmaşık bir boyut kazanmaktadır. Plansız arazi kullanımı, meraların ve orman alanlarının tarıma açılması, yanlış sulama teknikleri ve drenaj yetersizlikleri çevresel bozulmayı derinleştirmektedir. Erozyon, çölleşme ve biyolojik çeşitlilik kaybı gibi sorunlar, doğal kaynakların üretim kapasitesini azaltarak uzun vadede tarımsal sürdürülebilirliği tehdit etmekte; aynı zamanda ekonomik kayıplar ve sosyal sorunlara yol açmaktadır. Bu nedenle tarımsal çevre kirliliği, yalnızca yerel düzeyde ortaya çıkan bir üretim sorunu değil, küresel ölçekte etkileri hissedilen, disiplinler arası yaklaşımlar gerektiren karmaşık ve çok boyutlu bir problem olarak karşımıza çıkmaktadır. Dolayısıyla günümüzde tarımın temel hedefi yalnızca daha fazla üretmek değil; doğal kaynakları koruyarak, çevresel etkileri minimize ederek ve gelecek nesillerin ihtiyaçlarını gözeterek üretim yapmaktır. Sürdürülebilirlik ilkeleri, çevre dostu üretim teknikleri, entegre mücadele yaklaşımları, hassas tarım uygulamaları ve dijital teknolojiler bu dönüşümün önemli araçlarıdır. Tarım ile çevre arasındaki ilişkinin doğru analiz edilmesi ve bilimsel temelli çözümler geliştirilmesi, ekosistem sağlığının korunması ile gıda güvenliğinin sürdürülebilir biçimde sağlanması açısından hayati önem taşımaktadır.

Tarımsal Çevre Kirliliği kitabı, tarım ile çevre arasındaki çok boyutlu ilişkiyi bilimsel bir çerçevede ele alarak tarımsal faaliyetlerin çevre üzerindeki etkilerini, kirletici unsurları ve çözüm yaklaşımlarını kapsamlı biçimde ortaya koymayı amaçlamaktadır. Tarımsal üretim süreçlerinin doğal ekosistemlerle olan etkileşimi; kaynak kullanımı, kirletici oluşumu, taşınım mekanizmaları ve uzun vadeli çevresel sonuçları açısından sistematik bir bakış açısıyla değerlendirilmiştir. Bu kapsamda yalnızca sorunların tespiti değil, aynı zamanda risk analizi, izleme yöntemleri ve sürdürülebilir yönetim stratejileri de ele alınarak okuyucuya bütüncül bir perspektif sunulmuştur. Eserde; doğal kaynakların korunmasından ekosistem dinamiklerine, hava ve su kirliliğinden toprak kirliliğine, organik ve inorganik kirleticilerden ağır metal birikimine kadar geniş bir konu yelpazesi yer almaktadır. Tarımsal girdilerin çevredeki davranışı, toprak–bitki–su etkileşimleri, kirleticilerin biyoyararlanabilirliği ve besin zinciri yoluyla taşınımı bilimsel veriler ışığında açıklanmıştır. Bunun yanı sıra kirlilik giderim yöntemleri, fiziksel, kimyasal ve biyolojik arıtım teknikleri, fitoremediasyon ve biyoremediasyon uygulamaları detaylandırılarak uygulamaya dönük çözümler sunulmuştur. Toprak sağlığı kavramı, sürdürülebilir üretimle ilişkisi çerçevesinde ele alınmış; tarımsal kirliliğin insan sağlığı üzerindeki etkileri toksikolojik ve epidemiyolojik boyutlarıyla değerlendirilmiştir. Ayrıca çevre ekonomisi perspektifiyle, kirliliğin maliyeti, kaynak kullanım etkinliği ve sürdürülebilir tarım politikalarının ekonomik temelleri tartışılmıştır. Bu yönüyle eser, yalnızca akademik bir başvuru kaynağı değil, aynı zamanda karar vericiler ve uygulayıcılar için yol gösterici bir rehber niteliği taşımaktadır. Alanında uzman akademisyenler tarafından kaleme alınan bölümler, teorik bilgiyi ve güncel araştırma bulgularını içermekte; araştırmacılar, lisansüstü öğrenciler, kamu ve özel sektör çalışanları için önemli bir başvuru kaynağı niteliği taşımaktadır. Özellikle sürdürülebilir tarım, dijital dönüşüm, hassas tarım uygulamaları ve çevresel risk değerlendirmeleri gibi çağdaş yaklaşımlar, kitabın temel perspektifini güçlendirmektedir. Tarımsal çevre kirliliğinin yalnızca ekolojik bir mesele değil; aynı zamanda ekonomik, sosyal ve halk sağlığı boyutları olan disiplinler arası bir konu olduğu açıktır. Bu bağlamda kitap, çevresel farkındalığın artırılmasına, bilimsel temelli politika geliştirilmesine ve sürdürülebilir üretim modellerinin yaygınlaştırılmasına katkı sağlamayı hedeflemektedir.

Bu eserin ortaya çıkmasında emeği bulunan tüm bölüm yazarlarına, bilimsel birikimlerini ve akademik titizliklerini bu çalışmaya yansıttıkları için içten teşekkürlerimizi sunarız. Alanlarında uzman akademisyenlerin katkıları sayesinde kitap, tarımsal çevre kirliliği konusunu farklı boyutlarıyla ele alan, disiplinler arası bütünlüğe sahip bir eser niteliği kazanmıştır. Her bir bölüm, kendi uzmanlık alanının derinliğini yansıtırken aynı zamanda kitabın genel çerçevesiyle uyumlu bir yapı oluşturacak şekilde hazırlanmıştır. Bu çalışmanın hazırlanma sürecinde gösterilen özveri, iş birliği ve akademik sorumluluk anlayışı ve içeriklerin bilimsel doğruluğu, güncelliği ve kavramsal bütünlüğü konusunda gösterilen hassasiyet, eserin niteliğini güçlendirmiştir. Yayın sürecinde katkı

sunan tüm kişi ve kurumlara da teşekkür ederiz. Bu kitabın; araştırmacılar, lisansüstü öğrenciler, kamu ve özel sektör temsilcileri için güvenilir bir başvuru kaynağı olmasını; tarımsal çevre kirliliği konusunda bilimsel temelli değerlendirmelere ve çözüm odaklı yaklaşımlara katkı sağlamasını temenni ediyoruz. Sürdürülebilir tarım anlayışının güçlenmesine ve çevresel sorumluluk bilincinin yaygınlaşmasına katkı sunması en büyük beklentimizdir.

Unutulmamalıdır ki, doğayla uyumlu tarım, insanlığın en güçlü sigortasıdır.

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BÖLÜM 1

TARIM VE ÇEVRE İLİŞKİSİ: SORUNLAR, SÜRDÜRÜLEBİLİRLİK VE DİJİTAL DÖNÜŞÜM

Funda ERYILMAZ AÇIKGÖZ [1]
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GİRİŞ

21. yüzyılda küresel ölçekte yaşanan çevresel değişimler, tarım sektörünü hem etkileyen hem de tarımsal faaliyetler aracılığıyla şekillenen dinamik bir etkileşim alanı hâline getirmiştir. Artan dünya nüfusu, kentleşme, tüketim kalıplarındaki dönüşüm ve iklim krizi; gıda güvenliği, doğal kaynak yönetimi ve ekosistem hizmetlerinin sürdürülebilirliği açısından tarım-çevre ilişkisini stratejik bir gündem başlığına taşımaktadır. Tarımsal üretim, bir yandan toplumların temel gıda ihtiyacını karşılayan, kırsal istihdamı ve ekonomik büyümeyi destekleyen bir faaliyet alanı iken, diğer yandan yanlış arazi kullanımı, yoğun girdi kullanımı ve kontrolsüz üretim pratikleriyle toprak, su ve biyolojik çeşitlilik üzerinde baskı oluşturan temel sektörlerden biridir (1-6).

Bu bölümde, tarım ve çevre kavramlarının temel çerçevesi çizilmekte; tarımsal üretimde karşılaşılan genel sorunlar ele alınmakta ve tarım-çevre ilişkisi çevre sorunlarının sınıflandırılması bağlamında sistematik biçimde tartışılmaktadır. Böylece, çevre sorunlarının tarımsal sistemler üzerindeki etkileri ile tarımsal

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BÖLÜM 2

DOĞAL KAYNAKLAR: TOPRAK ÖRNEĞİ

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DOĞAL KAYNAKLAR

İnsan yaşamının sürdürülmesi ve ekonomik faaliyetlerin devamı için doğada doğal olarak meydana gelişinde insan müdahalesi olmayan veya çok sınırlı olan; enerji, besin, hammadde ve ekosistem hizmetleri sağlayan tüm oluşumlardır. Bu kaynaklar biyotik (canlı kökenli) ve abiyotik (cansız kökenli) bileşenlerden oluşur ve oluşumları doğal süreçlere ve yenilenme kapasitelerine göre farklılık göstermektedir. Toprak bilimi perspektifinden bakıldığında doğal kaynaklar; toprak, su, hava, bitki örtüsü, ormanlar, mera alanları, mineraller ve enerji kaynaklarını kapsayan bütüncül bir sistemdir. Bu sistem içerisinde **toprak** hem bir üretim ortamı hem de karbon depolama, besin elementi döngüsü, suyun tutulması ve biyolojik çeşitliliğin barındırılması gibi kritik ekosistem işlevleri nedeniyle stratejik bir doğal kaynak olarak kabul edilir. Bu çerçevede doğal kaynak kavramı, yalnızca fiziksel varlıkları değil, aynı zamanda bu varlıkların sağladığı ekosistem hizmetlerini de içine alan disiplinler arası bir yaklaşımı gerektirir. Sürdürülebilir yönetim anlayışı ise doğal kaynakların bugünkü gereksinimleri karşılarken gelecek nesillerin kullanım hakkını tehlikeye atmadan korunmasını esas alır. Doğal kaynaklar, hava, toprak, su, bitki örtüsü, hayvanlar ve madenler gibi çevrede

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Organik madde (humus), toprağın fiziksel özelliklerini iyileştirmesi, agregat stabilitesini artırması ve bitki besin elementleri için bir rezervuar görevi görmesi bakımından kritik öneme sahiptir. Ancak bu miktarın, toprak özellikleri ve çevresel koşullar çerçevesinde belirli bir denge seviyesinde bulunması gerekmektedir. Humus bünyesinde yaklaşık %5 oranında toplam azot bulunduğu varsayıldığında, 80 kg/da organik maddenin ayrışması sonucunda toprağa yaklaşık 4 kg/da azot kazandırılmaktadır. Azot:fosfor:kükürt oranının 10:1:1 olduğu kabul edilirse, aynı süreçte yaklaşık 0,4 kg/da fosfor ve 0,4 kg/da kükürt mineralize olarak bitkilerin yararlanabileceği forma dönüşmektedir (25).

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BÖLÜM 3

EKOSİSTEMLER

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EKOSİSTEM

Ekolojinin temel kavramlarından biri olan ekosistem, doğal çevrede yer alan canlı organizmalar ile bu organizmaların etkileşim içinde bulunduğu cansız unsurların oluşturduğu bir sistemi ifade eder. Sistemi meydana getiren varlıklar ve süreçler doğal nitelik taşıdığından bu yapı ekosistem olarak adlandırılmaktadır. Bu sebepten ekosistem; birbiriyle ilişkili canlı ve cansız unsurlardan oluşan, bu unsurlar arasında gerçekleşen madde ve enerji dolaşımı sayesinde kendini besleyebilen ve yenileyebilen fonksiyonel bir birimdir (1,2).

Bu tanım doğrultusunda ekosistem, belirli bir alanda bulunan canlı organizmalar ile bunların etkileşim hâlinde olduğu fiziksel ve kimyasal çevre koşullarının oluşturduğu dinamik bir bütün olarak değerlendirilmelidir (3,4). Ekosistemin işleyişi, yalnızca canlıların varlığına değil; enerji akışı, madde döngüleri ve canlı–cansız unsurlar arasındaki etkileşimlerin sürekliliğine dayanmaktadır. Bu yönüyle ekosistemler durağan yapılar olmayıp çevresel koşullar, iklimsel değişimler ve biyolojik ilişkiler doğrultusunda zaman içerisinde değişim ve dönüşüm gösterebilen dinamik sistemlerdir (4,5).

Ekosistem kavramı, ekolojinin kuramsal ve uygulamalı temellerini oluşturarak doğadaki denge mekanizmalarının anlaşılmasında kilit bir rol üstlenmektedir. Doğal ekosistemlerin sağlıklı bir biçimde işleyişi; biyolojik çeşitliliğin korunması,

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tırılması ile mümkündür. Bu bağlamda ekosistemlerin korunması, yalnızca ekolojik bir zorunluluk değil, aynı zamanda gelecek kuşaklara yaşanabilir bir çevre bırakmanın temel koşullarından biridir.

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BÖLÜM 4

TARIM VE HAVA KİRLİLİĞİ

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GİRİŞ

Hava kalitesi; gıda üretimi, halk sağlığı, çevresel sürdürülebilirlik ve ekonomik kalkınma ile doğrudan ilişkili olup küresel ölçekte kritik bir öneme sahiptir (1). Sanayileşme, hızlı kentleşme ve nüfus artışı, atmosfere salınan kirleticilerin miktarında belirgin bir artışa yol açmıştır (2). Partikül madde (2.5 μm $PM_{2.5}$ ve 10μm PM_{10}), troposferik ozon (yer yüzeyinden 15 km'ye kadar mesafede bulunan O_3), azot dioksit (NO_2), kükürt dioksit (SO_2), karbon monoksit (CO) ve uçucu organik bileşikler (VOC'ler) günümüzde hava kalitesinin bozulmasında başlıca rol oynayan kirleticiler arasında yer almaktadır (3,4). Bu kirleticiler; sanayi, enerji üretimi, ulaşım, atık yönetimi ve biyokütle yakımı gibi kaynaklardan atmosfere salınmakta ve atmosferik reaksiyonlar sonucunda ikincil kirleticilerin oluşumuna zemin hazırlayarak çok katmanlı bir kirlilik yapısı meydana getirmektedir.

Hava kirliliği, ekosistemler ve biyolojik çeşitlilik üzerinde olduğu kadar tarımsal üretkenlik üzerinde de belirgin baskılar oluşturmaktadır. Özellikle yer seviyesindeki yüksek ozon konsantrasyonları fotosentezi baskılayarak bitki dokularında oksidatif hasara neden olmakta ve verim kayıplarına yol açmaktadır (5). Yapılan çalışmalar, ozonun Sahra Altı Afrika'da buğday verimini %2–13 ora-

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BÖLÜM 5

TARIM VE SU KİRLİLİĞİ

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GİRİŞ

Tarım sektörü, dünya genelinde su kaynaklarını en yoğun kullanan ve aynı zamanda su kalitesi üzerinde önemli baskılar oluşturan temel faaliyet alanlarının başında gelmektedir. Günümüzde dünyada hızlı nüfus artışı ve buna bağlı olarak gıda ihtiyacındaki yükseliş, tarımsal üretimde daha fazla yoğunlaşmaya yol açmıştır. Bu durumda tarımda kimyasal girdilerin artmasıyla birlikte **noktasal olmayan ve yayılım kaynaklı su kirliliğini** dünyada küresel ölçekte önemli bir çevre sorunu haline getirmiştir. Son yıllarda nüfusun hızla artmasına karşın tarım alanlarının azalması sebebiyle ürünlerin miktarlarının artırılabilmesi için sulama, ilaçlama ve gübreleme gibi çeşitli uygulamalar gerçekleştirilmektedir. Bu önlemler bilinçli ve kontrollü şekillerde uygulanmadığında önemli ölçüde su kirliliğine neden olabilmektedir. Kimyasal gübreler arasında bulunan azotlu gübreler içme ve yeraltı sularına karışarak; fosforlu gübreler ise ötrofikasyon ile su kirliliğine sebebiyet vermektedirler. Pestisitler de fazla miktarlarda kullanıldıklarında içme sularına ulaşarak insan vücuduna girebilmekte ve bu durum da çeşitli hastalıklara neden olabilmektedir. İnsan eylemleri sonucunda su kaynaklarında doğal bileşimde yer alan maddelerin konsantrasyonlarının doğal sınırların üzerine çık-

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BÖLÜM 6

TARIM VE TOPRAK KİRLİLİĞİ

Mehmet SERTKAHYA [1]
Aydın ADİLOĞLU [2]

GİRİŞ

Toprak kavramı, ele alındığı bilim dalına göre farklı anlamlar kazanmaktadır. Yaşamın temeli olarak değerlendirilen ve doğal kaynaklar içerisinde özel bir yere sahip olan toprak, çeşitli disiplinlerde farklı biçimlerde tanımlanmakta; bu durum ortak bir tanımın oluşturulmasını güçleştirmektedir (1).

Tarım bilimi açısından toprak, arzın yüzeyini birkaç cm ile birkaç metre arasında örten, iklim ve canlıların ana materyal üzerinde karşılıklı etkileri sonucunda ortaya çıkan, bitkilerin kök saldığı, büyüyüp geliştiği ve yaşamını sürdürdüğü, çiftçilerin alın terini karşılığını aldığı, dinamik, üç fazlı, üç boyutlu doğal bir ortam olarak kabul edilmektedir (2). Organik ve inorganik bileşenlerin bir araya gelmesiyle oluşan karmaşık bir sistem olan toprak; katı, sıvı ve gaz fazlarını bir arada bulundurmaktadır. Toprağın katı fazı toprak gözeneklerinin yapısını belirleyerek su ve hava dolaşımını etkilemektedir. İnorganik bileşenler mineraller ve ayrışmış kayaç parçalarından, organik bileşenler ise bu mineral parçacıklarına bağlı organik madde ve onun çeşitli derecelerde ayrışmış bölümlerinden oluşmaktadır. Genel olarak ideal bir tarım toprağı yaklaşık olarak %50 katı madde (organik ve inorganik maddeler), %25 su ve %25 hava içeriğine sahiptir. Söz ko-

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BÖLÜM 7

TARIM VE ORGANİK KİTRLETİCİLER

Temine ŞABUDAK[1]

TARIM

Toprak, su ve hava faktörlerini kullanarak bitkisel ve hayvansal organik maddeleri üretme bilim ve tekniğidir. Genel olarak, ekolojik anlamda da toprak, su ve hava etkenlerini en iyi biçimde değerlendiren organizmalarla, bitkisel ve hayvansal organik maddeleri üretme bilim ve tekniği olarak ta tanımlanan tarım, insanlığın var oluşundan bu yana yoğunlaşarak devam eden bir uğraştır (1).

Binlerce yıl doğal ortam koşularında, doğayla uyumlu bir biçimde yapılan tarımsal faaliyetler çevreye zarar vermemiş ve çevre sorunlarına neden olmamıştır. Ancak, tarımda uygulanan yapay unsurlar, endüstriyel gelişme, artan dünya nüfusu ve kentsel yaşamın beraberinde getirdiği çevre kirliliği, yirminci yüzyılın ikinci yarısından itibaren çevresel bozulmayı da hızlandırarak, doğal yaşamı tehdit altına almış bulunmaktadır. Bununla birlikte, doğal kaynak yıpranması hızlanmış, özellikle tarım sektöründe etkisini göstermiştir. Ekosistemi kirleten tarımsal uygulamaların sürdürülebilir düzeyde olmadığı görülmektedir. Özellikle nüfus artması sebebine bağlı olarak temel ihtiyaçların karşılanmasına yönelik baskılar nedeni ile insanlar "ekoloji" den çok "ekonomi" yi, düşünür hale gelmiştir. Günümüzde, tarımsal üretim ve verimlilik, yeni ve yüksek kapasiteli ürün çeşitlerinin geliştirilmesi sayesinde kayda değer ölçüde yükselmiştir. Ancak, bu yüksek verim düzeyi, sürekliliğini koruyabilmek için, daima zararlılarla müca-

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denge bozulmakta ve bitkilerde kimyasal kaynaklı zehirlenmeler (fitotoksisite) ortaya çıkmaktadır (49).

Bu çerçevede, toprağı ve yer altı su kaynaklarını kirleten tarımsal mücadele ilaçlarının kullanımında ya yarılanma ömürleri hassasiyetle dikkate alınmalı ya da toprak organizmaları ve insan sağlığı üzerinde olumsuz etkileri bulunmayacak şekilde biyolojik mücadele yöntemlerine geçilmelidir. Sanayi ve nükleer tesislerin kurulumu, tarım arazilerinden ve yerleşim yerlerinden uzak bölgelerde gerçekleştirilmelidir. Kirliliğe neden olan tüm atıklar, türlerine göre dikkatlice sınıflandırılıp planlı bir biçimde toplanmalı ve arıtılmadan kesinlikle toprağa bırakılmamalıdır. Atık materyallerin yeniden değerlendirilmesi amacıyla, geri kazanım ve arıtma tesislerinin kurulmasına öncelik verilmelidir. Ayrıca, çevreye verilen zararı en aza indirmek için gerekli kanun ve yönetmelikler hızla çıkarılmalı, bu kurallara uymayanlar hakkında gereken cezai işlemler uygulanmalıdır. Çevre duyarlılığı gösteren ve bu konuda çaba harcayan kişi veya kurumlar için, başkalarını teşvik edici nitelikte ödül törenleri düzenlenmeli ve bu tür çalışmaların medya tarafından desteklenmesi sağlanmalıdır.

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BÖLÜM 8

İNORGANİK KİRLETİCİLER: AĞIR METAL KİRLİLİĞİ

Çağdaş AKPINAR[1]

GİRİŞ

İnorganik kirleticiler (özellikle ağır metaller) çoğunlukla antropojenik kaynaklardan kaynaklanır ve toprak-bitki ilişkisinde yoğunlaşır; bu nedenle varlıkları büyük bir çevre sorunudur. Ayrışma sürecinde, ana materyalden toprağa inorganik kirleticiler katılır; bu kirleticiler genellikle 1000 mg kg^{-1}'den az olup, zaman zaman tehlikeli olabilmektedir (1). Jeokimyasal döngü, metal seviyelerini hem kırsal hem de kentsel alanlarda kademeli olarak tehlikeli bir noktaya çıkarır; bu da flora, fauna ve çevre için yeterli bir tehlike oluşturur (2). Ağır metaller terimi genellikle yoğunluğu 5,0 g cm^{-3}'ten büyük elementleri ifade eder ve kirlilik ve toksisite ile ilişkili metalleri ve metaloidleri belirtir. Ancak organizmalar tarafından oldukça düşük konsantrasyonlarda ihtiyaç duyulan elementleri de içerir (3).

Gıda güvenliğinin eksikliği ve sağlık üzerindeki tehlikeler, tartışmasız çevre sorunlarıyla birlikte endişe verici bir durum yaratmaktadır (4). Organik kirleticilerden farklı olarak, ağır metaller biyolojik veya kimyasal olarak parçalanamaz, ancak toprakta kalıcıdırlar. Örneğin, Kadmiyum (Cd) toprakta 18 yıldan fazla, Kurşun (Pb) ise 150-5000 yıl kalabilmektedir (5). Ağır metaller, toprak mikroorganizmalarının dağılımını, işlevsel aktivitesini ve çeşitliliğini ve ayrıca karbon ve besin döngüsünde rol oynayan enzimlerin salınımını olumsuz etkiler (6,7). Bitkilerde biriktiklerinde, ağır metaller reaktif oksijen türleri üreterek

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leri olsa da fazlalıkları zararlı etkilere neden olabilir ve bitki büyümesini, metabolizmasını, fizyolojisini ve yaşlanmasını doğrudan etkileyebilir. Ağır metaller kirliliği ekosistem için ciddi bir sorun ve biyota için büyük bir sağlık riski haline gelmektedir. Ayrıca, ağır metallerin tarımımız üzerindeki olumsuz etkileri gıda güvenliği ve emniyeti açısından ciddi bir endişe kaynağı olmaktadır. Bu nedenle, ağır metallerin çevreden uzaklaştırılması için kalıcı bir çözüm yolu bulunması gerekmektedir.

Önceki araştırmalar ayrıca ağır metallerin, antioksidan savunma sistemlerindeki değişiklikler, belirli enzimlerin biyolojik aktivitelerinin bozulması, bitkilerde kloroz, nekroz, oksidatif stres, klorofil a ve b›nin azalması, fotosentezin etkilenmesi, büyümenin bozulması gibi bitki fizyolojik işlevlerinde çeşitli değişikliklere yol açtığını vurgulamıştır.

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BÖLÜM 9

TARIM VE BİTKİSEL ATIKLAR

Özlem ÜSTÜNDAĞ [1]
Mehmet SERTKAHYA [2]

GİRİŞ

Dünya nüfusu, 1970 yılında 3,7 milyarken 2021 yılında 7,9 milyara ulaşmıştır. Artışın bu şekilde devam etmesi halinde, dünya nüfusunun 2050 yılında 9 milyar, 2100 yılında ise 11 milyara ulaşacağı öngörülmektedir (1). Nüfus ile tüketim ihtiyacının önlenemez artışı, sanayileşme ve tüketici alışkanlıklarında meydana değişimler, atık miktarının artmasına neden olmaktadır. "Atık" atılan veya atılması planlanan malzemeler veya süreçler olarak tanımlanmaktadır. Bu genel tanım, ev çöpünden, tarımsal atığa, gıda endüstrisi atığından endüstriyel atığa kadar «atık» olarak sınıflandırılan maddelerin hepsini kapsamaktadır (2,3). Taleplerin tarımsal üretimde meydana getirdiği artış, tarımsal atıkların oluşumunda da artışa neden olmaktadır (1). Çünkü her zaman tarım, en yüksek biyokütleyi üreten sektörlerden biri olmuştur (4,5). Bitkisel ve hayvansal atıkları gömmek ya da yakmak yerine ekonomiye kazandırmak; hem gıda güvenliği ve çevresel sürdürülebilirliğe hizmet etmekte hem de kırsal alanda yeni istihdam olanakları yaratarak çiftçilerin refah düzeyini arttırmaktadır (6,7). Ayrıca bu süreç, yalnızca tarımsal atık ve yan ürünlerin değerli kaynaklara dönüştürülmesiyle yeşil pazarlar ve istihdam olanakları yaratmakla kalmaz, aynı zamanda çevre kirliliğini azal-

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BÖLÜM 10

TOPRAK KİRLİLİK GİDERİM YÖNTEMLERİ

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GİRİŞ

İnsanlık tarihi boyunca çevre kirliği denildiğinde akla ilk gelen temel sorunlardan biri de toprak kirliliğidir. Toprak kirliliği aynı zamanda tarımsal ürünler aracılığıyla insan sağlığını da hedef alan bir sorundur. Toprak kirliliği, yalnızca ekosistem fonksiyonlarını zayıflatan bir çevre sorunu değil, aynı zamanda doğrudan ve dolaylı yollarla insan sağlığını etkileyen önemli bir risk faktörüdür. Kirlenmiş topraklarda biriken ağır metaller (örneğin kurşun, kadmiyum, arsenik), kalıcı organik kirleticiler, pestisit kalıntıları ve petrol türevleri; bitkiler aracılığıyla gıda zincirine taşınabilmekte, yer altı ve yüzey sularına sızarak içme suyu kaynaklarını tehdit edebilmekte ya da toz partikülleri yoluyla solunum sistemi üzerinden insan vücuduna girebilmektedir. Bu kirleticilerin biyoyararlanabilir fraksiyonu, toprak pH'sı, organik madde düzeyi ve redoks koşulları gibi pedolojik özelliklere bağlı olarak değişmekte; dolayısıyla maruziyet riski sabit değil, dinamik bir karakter göstermektedir (1).

Toprak, biyosferin en karmaşık ve işlevsel bileşenlerinden biri olup; besin üretimi, su filtrasyonu, karbon depolanması ve biyolojik çeşitliliğin sürdürülmesi gibi çok yönlü ekosistem hizmetleri sunmaktadır. Ancak sanayileşme, yoğun tarımsal

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teyi artırması hem de organik kirleticilerin biyodegradasyonunu hızlandırması nedeniyle dikkat çekmektedir. Ayrıca kompost, ağır metallerin parçalanmasını sağlayamasa da humik maddeler aracılığıyla kompleksleşme, adsorpsiyon ve pH düzenleme yoluyla metallerin mobilitesini azaltarak çevresel riski doğrudan düşürmektedir. Bu yönüyle kompost, özellikle giderim yerine stabilizasyon ve risk azaltımını hedeflenen ağır metal kirlenmelerinde önemli bir remediasyon materyalidir. Sonuç olarak, sürdürülebilir toprak yönetimi açısından en uygun remediasyon yaklaşımı; kirleticiye özgü seçilmiş teknolojilerin, çevresel risk azaltımı hedefiyle, saha koşullarına göre optimize edilmesi ve mümkün olduğunda toprak sağlığı bileşenlerini iyileştiren uygulamalarla desteklenmesidir. Bu çerçevede fitoremediasyon, bioremediasyon, kompost, kimyasal oksidasyon ve diğer fiziksel/kimyasal/biyolojik yöntemler, birbirinin alternatifi olmaktan çok, doğru tasarlandığında birbirini tamamlayan bileşenler olarak değerlendirilmelidir.

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BÖLÜM 11

FİTOREMEDİASYON VE TARIM

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GİRİŞ

Bitkisel üretim, hayvansal üretim, su ürünleri ve ormancılık gibi birçok faaliyet alanını içeren tarımsal üretim, katma değeri yüksek ekonomik bir aktivasyondur. Tarımsal üretimin temel alt dallarını içeren tarla bitkileri, bahçe ve diğer bitkisel ürünlerin yetiştirilmesini içermektedir. Tarımsal üretim; tahıllar, baklagiller, sebzeler ve meyveler başta olmak üzere geniş bir ürün yelpazesini kapsamakta olup tarımsal üretim içinde önemli bir paya sahiptir. Gerek insan gıdası gerekse hayvancılık faaliyetleri için yem kaynağı oluşturması, bu üretim alanını tarımın diğer alt dallarıyla bütünleşik hale getirmekte ve sürdürülebilir tarımın temel unsurlarından biri konumuna getirmektedir. Bu denli geniş bir ürün yelpazesini kapsayan ve gıda güvenliğinin temelini oluşturan tarımsal üretimin devamlılığı, toprak ve çevre kaynaklarının sürdürülebilir biçimde yönetilmesine bağlıdır. Buna karşın, tarımsal üretimin artan önemine paralel olarak uygulanan üretim yöntemleri, doğal kaynaklar üzerinde giderek artan baskılar oluşturmakta ve çevresel sorunları beraberinde getirmektedir. Tarım alanlarının kendini yenileme kapasitesi giderek azalmakta ve ciddi kirlilik tehdidi altında bulunmaktadır. Tarımsal üretimde yapılan hatalı ve bilinçsiz gübreleme uygulamaları, bu kirlilik sürecinde önemli bir etken olarak öne çıkmaktadır. Bununla birlikte Dünya nüfu-

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SONUÇ VE DEĞERLENDİRME

Çevredeki kirletici konsantrasyonları her geçen yıl artış göstermektedir. Bu nedenle, kirlenmiş toprakların dekontaminasyonu, çevresel sağlığın korunması ve ekolojik restorasyonun sağlanması açısından büyük önem taşımaktadır. Organik ve inorganik kirleticelerin toprakta uzun süre kalıcı olması, besin zincirine girme potansiyeli ve canlı organizmalar üzerinde toksik etkilere yol açması, bu kirleticilerin etkin şekilde giderilmesini zorunlu kılmaktadır. Fitoremediasyon, kirlenmiş ortamların temizlenmesi veya stabilize edilmesi amacıyla bitkilerin kullanıldığı yenilikçi bir iyileştirme yaklaşımıdır. Kirliliğinin giderilmesinde fitoremediasyon, bitki temelli yöntemler arasında en etkili ve çevre dostu tekniklerden biri olarak öne çıkmaktadır. Bu yeşil teknoloji, toprağın fiziksel, kimyasal biyolojik yapısına zarar vermeden kirlenmiş alanların iyileştirilmesine imkân tanımakta; böylece geleneksel kazı ve taşıma yöntemlerinin yol açtığı yapısal bozulmaların önüne geçmektedir. Bazı otsu ve odunsu bitki türlerinin toksik metalleri önemli düzeylerde absorbe edebildiği bilimsel çalışmalarla ortaya konmuştur. Bu bitkiler, metalleri köklerinden alarak dokularında biriktirme yetenekleri nedeniyle hiperakümülatör bitkiler olarak tanımlanmaktadır. Hiperakümülatör türler, ağır metal kirliliği bulunan sahalarda fitoekstraksiyon (phytoextraction) ve fitostabilizasyon gibi uygulamalarda önemli bir potansiyele sahiptir. Bu özellikleri sayesinde, hem çevresel risklerin azaltılmasına katkı sağlamakta hem de sürdürülebilir arazi yönetimi ve ekosistem restorasyonu çalışmalarında etkili bir araç olarak değerlendirilmektedir.

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BÖLÜM 12

BİYOREMEDİASYON VE TARIM

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GİRİŞ

Çevre kirliliği son birkaç on yılda sıkça duyduğumuz bir kavram. Özellikle çevre bilincinin oluşmasına paralel olarak birçok bilim dalının ilgisini çekmiş ve hem bilim insanlarının hem çevre aktivistlerinin kanun koyucuların dikkatlerini çekmek için çabaladıkları bir kavram olarak gündemde kalmaktadır. Nitekim, gözle görünsün görünmesin, etrafında olsun olmasın her insanı yakından ilgilendiren bir problemdir. Yaşadığımız yere bağlı olarak hava kirliliğinin etkisini kolayca fark edebiliriz. Su kaynaklarının kirliliği, kirliliğin boyutuna bağlı olarak gözle görünür duruma geldiğinde, kıyılarda kendini hissettirdiğinde ya da kritik bir hal aldığında dikkatimizi çekebilir. Kirlilikten bahsettiğimizde çok farkında olmadığımız bir diğer ekosistem elemanı da topraktır. Hava ve su kirliliğinin bizi etkilediği kadar, belki de daha çok ve daha derinden, toprak kirliliğinden de etkileniriz. İnsan beslenmesinin temelini oluşturan tarımın ana parametresi toprağın kirliliği besin zinciri yoluyla insana ulaşarak çok çeşitli hastalıklara yola açar. Tam da bu sebeple, beslenme amacıyla her geçen gün daha fazla toprağı ekim alanı olarak değerlendirmek için tarıma açtığımız göz önünde bulundurulduğunda, topraktaki kirliliğin temizlenmesinin önemi daha da artmaktadır.

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BÖLÜM 13

TARIMSAL KİRLİLİK VE TOPRAK SAĞLIĞI

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GİRİŞ

Dünya, insanoğlunun yerleşik hayata geçtiği Holosen döneminden itibaren hızlı nüfus artışı ve yerleşik uygarlıkların yükselişiyle birlikte belirgin çevresel değişimler yaşamıştır. Özellikle 18. yüzyılın sonlarında ivme kazanan sanayileşme, kentleşme ve tarımsal yoğunlaşma ise, literatürde "Antroposen" olarak adlandırılan ve insan etkisinin belirleyici hâle geldiği yeni ve kritik bir döneme geçişi temsil etmektedir (1). Antroposen, insan etkinliklerinin ölçeği ve hızının, kirleticilerin doğal ortamlara taşınmasını ve yayılımını artırarak jeobiyokimyasal döngüleri ve ekosistem işleyişini kökten dönüştürdüğü bir çağdır. Kirlilik; atmosfer, hidrosfer ve litosfer dâhil olmak üzere Dünya sistemlerine istenmeyen ya da aşırı miktarda madde veya enerjinin girmesi sonucu, organizmalar ve ekosistemler üzerine olumsuz etkilerin ortaya çıkma sürecidir. Kirleticiler sentetik ya da doğal kökenli kimyasallar olabileceği gibi, ses, ısı veya ışık biçimindeki enerji fazlalıklarını da kapsayabilir. Bu bağlamda kirlilik; hava, su (yüzey ve yeraltı), toprak, plastik, ışık, gürültü, termal, görsel ve radyoaktif kirlilik ile katı atık/çöp gibi pek çok kategoride ortaya çıkmaktadır (2). Bu kategoriler içinde özellikle toprak, yüzey akış suyu, yeraltı suyu ve hava kirliliği; insan sağlığı, biyoçeşitlilik

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BÖLÜM 14

TARIMSAL KİRLİLİK VE İNSAN SAĞLIĞINA ETKİLERİ

Ayşe Handan DÖKMECİ[1]

GİRİŞ: TARIMSAL ÜRETİMDEN KÜRESEL HALK SAĞLIĞI SORUNUNA

Tarımsal üretim, gıda güvenliği ve kırsal kalkınma açısından vazgeçilmezdir. Bununla birlikte artan nüfus ve gıda talebiyle yükselen verim baskısı, modern tarım sistemlerinde kimyasal girdilere bağımlılığı belirgin biçimde artırmıştır. Sentetik gübreler, pestisitler (insektisit, herbisit, fungisit vb.) ve veteriner uygulamaları kısa vadede ürün kayıplarını azaltıp üretimi yükseltebilse de, uzun vadede su, toprak ve gıda zinciri üzerinden çevresel kirlenmeye ve insan sağlığı risklerine zemin hazırlayabilmektedir (1,2) (Şekil 1).

Bu nedenle tarımsal kirlilik yalnızca çevre mühendisliği veya tarım bilimlerinin değil; halk sağlığı, toksikoloji, çevre hukuku, risk yönetişimi ve sağlık politikası disiplinlerinin kesişiminde yer alan çok boyutlu bir sorundur (2). Güncel çalışmalar, pestisit maruziyetinin kanserler, nörodejeneratif hastalıklar, endokrin bozukluklar ve solunum hastalıkları gibi çeşitli kronik sonlanımlarla ilişkili olabileceğini; özellikle tarımsal işgücü ve kırsal topluluklarda mesleki ve çevresel maruziyetin süreğen bir risk kaynağı oluşturduğunu göstermektedir (3-5).

Akut zehirlenmeler tarımda uzun süredir bilinen bir problem olmakla birlikte, düşük doz–uzun süreli ve karışım maruziyetlerine ilişkin kanıt birikimi tarımsal kirliliği küresel ölçekte büyüyen bir halk sağlığı önceliğine dönüştürmüştür (3,5).

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BÖLÜM 15

ÇEVRE EKONOMİSİ VE TARIM

Süreyya BAKKAL[1]

GİRİŞ

Tarımsal üretim; gıda güvenliği, kırsal istihdam ve bölgesel kalkınma açısından stratejik bir sektördür. Bununla birlikte tarım, toprak ve su gibi doğal kaynaklara doğrudan bağımlı olduğu için çevresel bozulmalardan hızla etkilenir; aynı zamanda üretim sürecinde ortaya çıkan bazı etkiler yoluyla çevresel bozulmayı hızlandırabilir (19,21).

İklim değişikliği, biyoçeşitlilik kaybı ve toprak bozulumu gibi süreçler, tarım sistemlerinin sürdürülebilirliğini belirleyen temel baskılardır. Bilimsel değerlendirmeler, gıda sistemlerinin hem sera gazı salımlarını azaltma hem de ekosistemlerin taşıma kapasitesi içinde gıda arzını güvence altına alma zorunluluğu ile karşı karşıya olduğunu vurgulamaktadır (9,10,19,31).

Tarımın çevre ile ilişkisi yalnızca biyofiziksel bir konu değildir; aynı zamanda ekonomik bir konudur. Çünkü birçok çevresel etki piyasada fiyatlanmaz ve üretici ile tüketicilerin kararlarına doğrudan yansımaz. Çevre ekonomisi; dışsallıklar, ortak havuz kaynakları ve kamu malları gibi piyasa aksaklıklarını analiz ederek, tarımda çevresel kirliliğin azaltılması için uygulanabilir politika araçlarını tartışmaya imkân verir (1,3).

Bu bölümün amacı çevre ekonomisinin temel kavramlarını tarımsal çevre kirliliği bağlamına uyarlamak; tarımsal faaliyetlerden kaynaklanan kirliliğin

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kirlilik, izleme ve doğrulama maliyetlerini yükselttiği için; uygulama temelli düzenlemeler, hedefli ödemeler ve bilgi araçlarının birlikte tasarlandığı karma politika paketleri çoğu zaman daha uygulanabilir sonuçlar üretir (23,32).

Politika tasarımında aşağıdaki ilkeler öne çıkmaktadır:

» Hedefleme ve önceliklendirme: Hassas havzalar, içme suyu besleme alanları ve erozyon riski yüksek araziler gibi alanlarda daha sıkı koruma ve destekleme tasarımı yapılmalıdır (14,22).
» Teşvik uyumu: Destekleme sistemleri, çevreye zararlı uygulamaları dolaylı olarak teşvik etmeyecek biçimde gözden geçirilmeli; çevresel koşulluluk ve sonuç odaklı ödemeler güçlendirilmelidir (32).
» Veri ve izleme altyapısı: Su kalitesi, toprak sağlığı ve emisyon göstergelerini izleyen sistemler; modelleme ve karar destek araçlarıyla birlikte geliştirilmelidir (15,23).
» Sağlık ve refah boyutu: Pestisit ve hava kirliliği gibi risklerde sağlık etkileri politika değerlendirmesine sistematik biçimde dahil edilmeli; önleme yaklaşımı benimsenmelidir (25,24).
» Geçişin yönetimi: Çiftçilerin çevre dostu uygulamalara geçiş maliyetlerini azaltmak için eğitim, danışmanlık, teknoloji erişimi ve finansman araçları paket halinde sunulmalıdır (31).
» Kuşaklar arası adalet ve sınırlar: Doğal sermayenin kritik bileşenleri ve ekosistem eşikleri dikkate alınarak, kısa vadeli verim artışı ile uzun vadeli sürdürülebilirlik arasında denge kurulmalıdır (5,8).

Sonuç olarak, tarımsal çevre kirliliğinin azaltılması; çevresel hedeflerin net tanımlanması, doğru ölçek (parsel-havza-bölge) seçimi, güvenilir izleme ve teşvik uyumunun sağlanmasıyla mümkündür. Çevre ekonomisi araçları, bu süreçte hangi politika bileşenlerinin daha maliyet-etkin ve uygulanabilir olacağını değerlendirmek için güçlü bir analitik temel sunmaktadır (3,4,23).

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