Global Change Biology

Conceptualizing soil organic matter into particulate and mineral–associated forms to address global change in the 21st century

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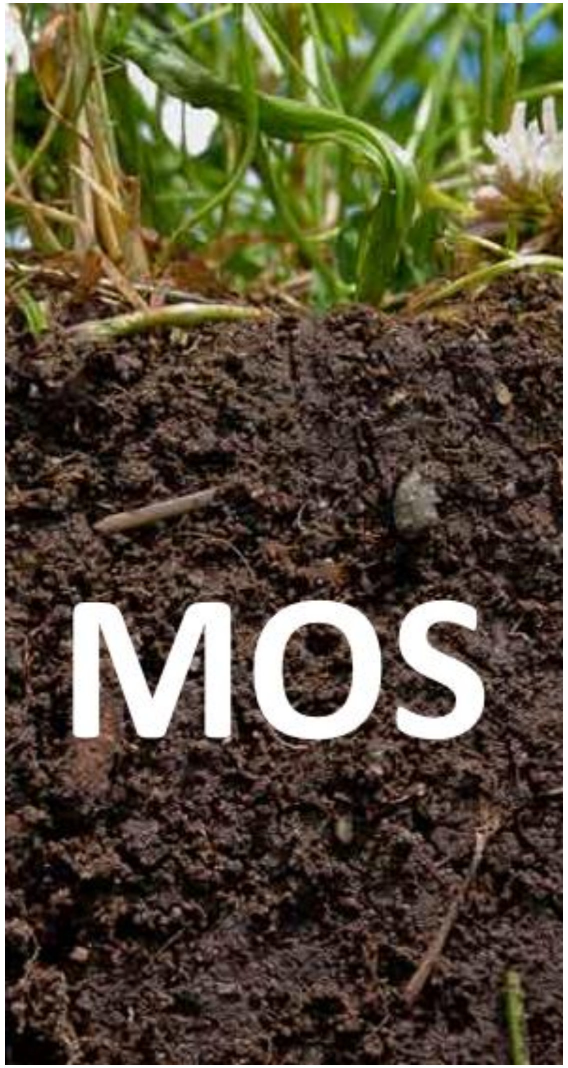
A IMPORTÂNCIA DA MOS

COMO ANALISAR?



FRACIONAMENTO → QUÍMICO → SUBSTÂNCIAS HÚMICAS

FRACIONAMENTO → FÍSICO → DENSIDADE → MOP / MOAM

FRACIONAMENTO → FÍSICO → TAMANHO → MOP / MOAM

PROBLEMA

“Together, the explosion of new knowledge—much of it context specific—and the myriad methodological approaches to studying SOM led to a muddling of ideas.”

- Dificulta a comparação entre estudos realizados em locais e contextos diferentes

- Induz estudos em larga escala a erros ao estudar a MOS como substância homogênea

PROPOSTA

ABORDAGEM MAOM vs. POM

- Abordagem simples, informativa e aplicável a estudos em escala global;
- Possibilita a compreensão em diferentes ecossistemas, profundidades de solo e escalas de tempo;
- Melhor forma de :
  - conceituar resultados de estudos sobre MOS,
  - identificar agentes de acumulação de MOS,
  - prever alterações nos estoques de MOS,
  - basear políticas e práticas de manejo que visem conservar ou regenerar a MOS.

MOAM E MOP: DIFERENÇAS

TABLE 1 The general properties of particulate (POM) and mineral-associated (MAOM) organic matter discussed in this review with references of relevant studies

	POM	MAOM	References
Protection mechanisms	None or occlusion in large aggregates	Mineral associations (occlusion in fine aggregates, organo-mineral clusters, and micropores; sorption to mineral surfaces)	von Lützow et al. (2007)
Mean residence time	<10 years—decades	Decades—centuries	Kleber et al. (2015), Kögel-Knabner et al. (2008), von Lützow et al. (2007)
Dominant formation pathway	Fragmentation, depolymerization	In vivo transformation or ex vivo modification of low molecular weight compounds	Cotrufo et al. (2015), Liang et al. (2017)
Subject to saturation?	No	Yes	Castellano et al. (2015), Cotrufo, Ranalli, Haddix, Six, and Lugato (in press), Stewart et al. (2008)
Dominant chemical constituents	Plant-derived (e.g., phenols, celluloses, hemicelluloses), fungal-derived (e.g., chitin, xylanase)	Low molecular weight compounds of microbial (e.g., microbial polysaccharides, amino sugars, muramic acid) and plant origin	Baldock and Skjemstad (2000), Christensen (2001), Kögel-Knabner et al. (2008), Sanderman et al. (2014), Six et al. (2001)
C/N ratio	10–40	8–13	Cotrufo et al. (in press), von Lützow et al. (2007)
Nutritional role	• More complex compounds with high activation energies • Not assimilable by plants, few or no assimilable compounds for microbes	• More simple compounds with low activation energies • More assimilable compounds for microbes and plants	Jilling et al. (2018), Kleber et al. (2015), Williams et al. (2018)

Composição

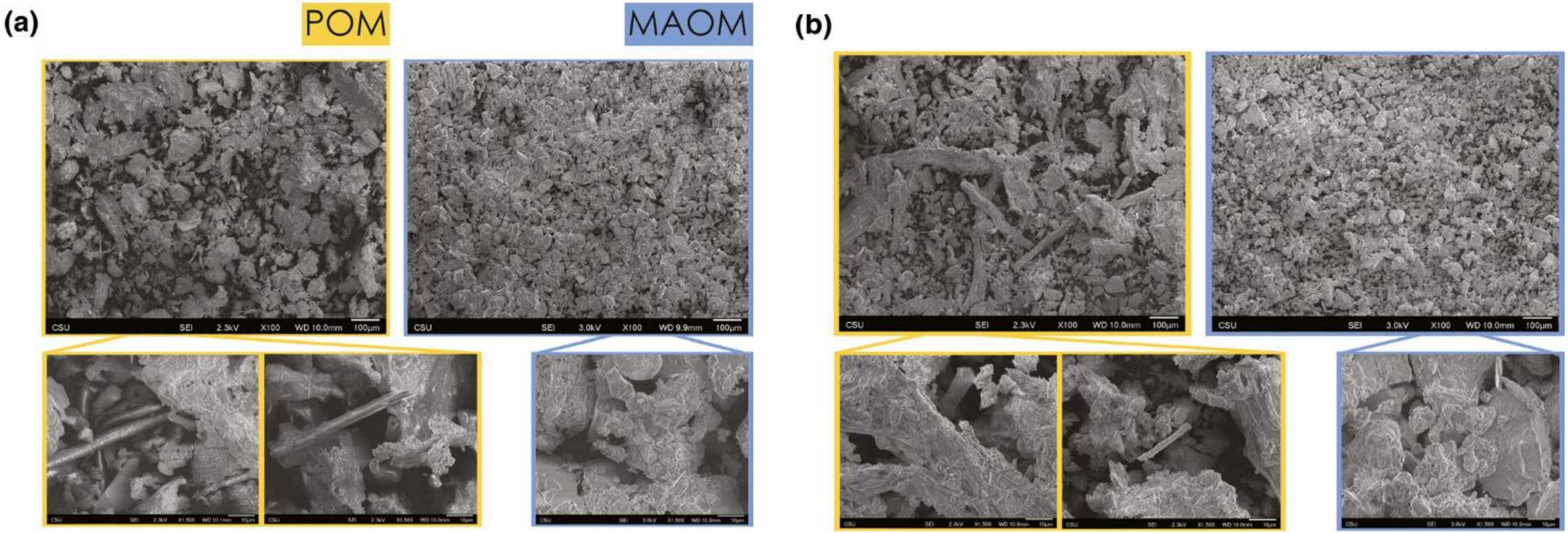


FIGURA 1 Scanning electron microscope images of particulate (POM; left) and mineral-associated (MAOM; right) organic matter, including larger overviews and closer details, from **(a) deciduous forest and (b) grassland**. Samples are from A horizons collected by the National Ecological Observatory Network (NEON) from the Bartlett Experimental Forest in New Hampshire and the Northern Great Plains Research Laboratory in North Dakota, respectively, and separated at Colorado State University by size (53 µm) and density (1.8 g/cm3). Detail images show distinct plant and/or fungal structures in POM samples and clustered organo-mineral structures in MAOM samples

DIFERENÇAS

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Formação

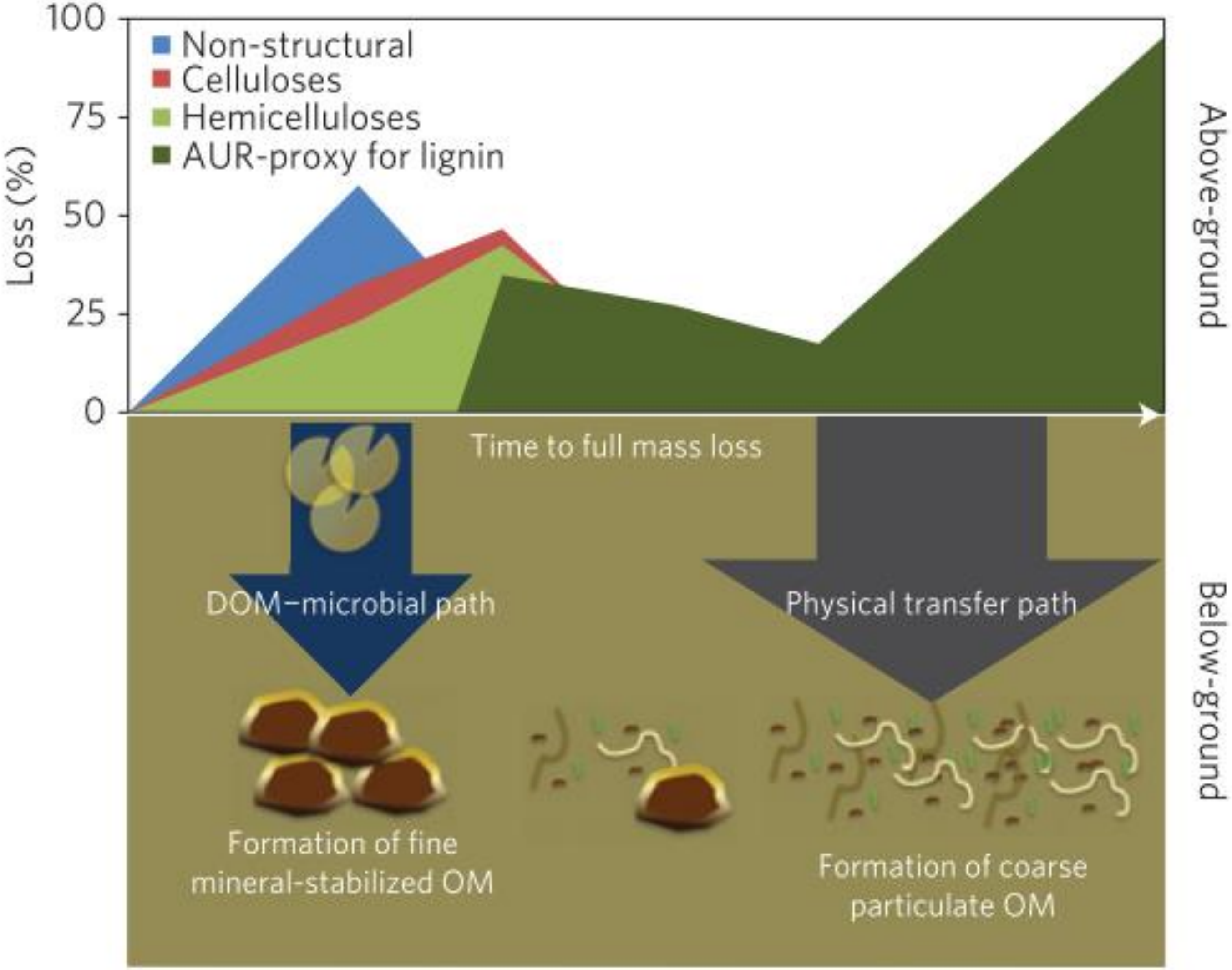

FIGURA 2 | Schematic representation of biochemical and physical pathways leading to SOM formation from progressive loss of litter chemical components. Each component loss is in percentage of its initial weight. Data are averages (n=4). Initially, the acid unhydrolysable fraction (AUR) gained mass; thus, its loss is higher than 100% initial weight. The DOM–microbial path is important during early stages of litter decomposition, when litter loses mostly non-structural soluble compounds that are efficiently incorporated by microbes, resulting in mineral-associated fine organic matter (OM). Later, brittle litter residues move in the mineral soil by physical transfer where they form coarse particulate organic matter

Fonte: Cotrufo et al., 2015

Formação

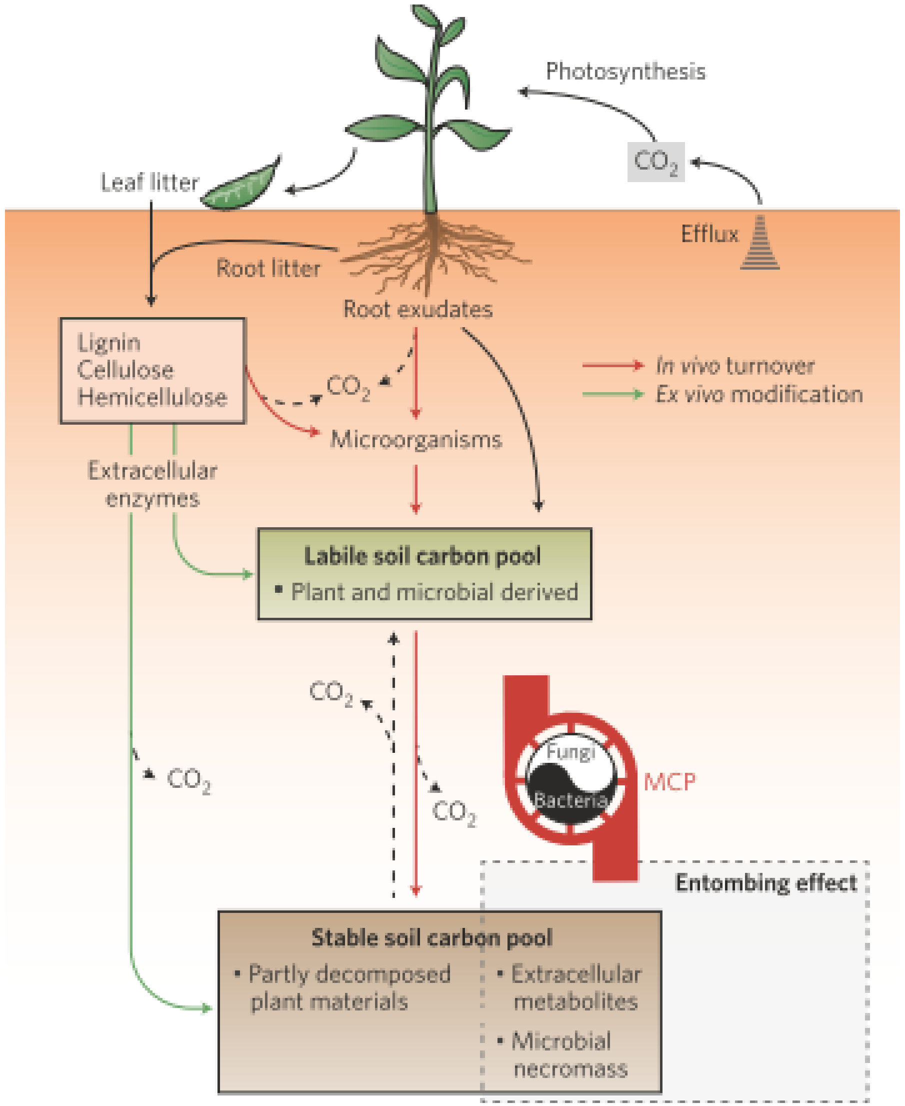

FIGURA 3| Schematic diagram of microbial metabolic processes involved in C cycling in terrestrial ecosystems. Primary production inputs to soils occur through two pathways—in vivo turnover and ex vivo modification— that jointly explain soil C dynamics driven by microbial catabolism and/or anabolism before entering the stable soil C pool. Even though the relative importance of in vivo turnover (red lines) and ex vivo modification (green lines) vary with different environmental scenarios, we argue that the majority of C that is persistent in soils occurs through coupling of the soil microbial carbon pump (MCP; associated with the in vivo turnover pathway) to stabilization via the entombing effect. The soil MCP is a conceptual object to demonstrate the fact that microbial necromass and metabolites can be the precursors for persistent soil C, which particularly highlights the importance of microbial anabolism in soil C storage. The yin–yang symbol is used to create a sense of movement and illustrate that the movement is driven, but driven differently, by both bacteria and fungi with different trophic lifestyles

Fonte: Liang et al., 2017

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MAOM E POM: DEFINIÇÕES OPERACIONAIS

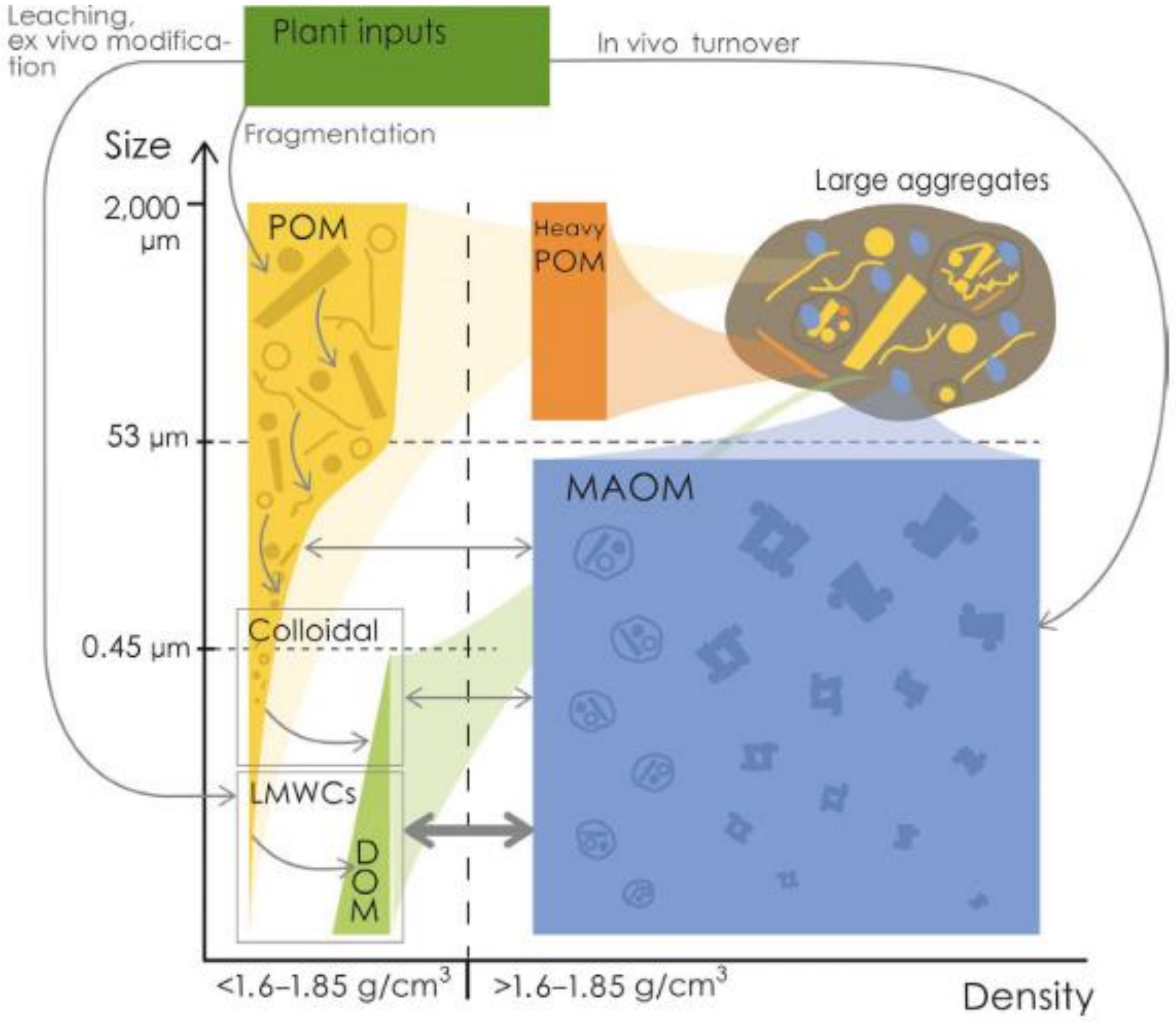


FIGURE 4 Conceptual representation of major soil organic matter (SOM) components discussed in this review. These SOM components are physically defined based on size and density, shown on the y and x axes, respectively. The upper size limit specification for MAOM varies by region, from 20 to 63 µm; we show 53 µm here for simplicity. Dissolved organic matter (DOM) is generally defined as <0.45 µm and water-extractable. Mineral-associated organic matter (MAOM) has multiple forms, including small particulate organic matter (POM)-like structures encapsulated by minerals, organo-mineral clusters, and primary organo-mineral complexes. Large aggregates can contain all other components to varying degrees. LMWCs are low molecular weight compounds. Arrows leading from plant inputs to different components represent hypothesized SOM formation pathways

RESPOSTAS CONTRASTANTES DE MOP E MOAM PARA FATORES DE MUDANÇA GLOBAL

Mecanismos de persistências da MOS:

Espaciais

Oclusão

Inibição Microbiana

pH

Eh

Name	Constituents	Upper size limit	Lower size limit	References that use this definition
Macroaggregates	Smaller macroaggregates, microaggregates, POM, MAOM[a]	2,000 µm	250 µm	Totsche et al. (2018)
			212 µm	Jastrow (1996)
			200 µm	Puget et al. (2000)
Microaggregates, or large microaggregates	Smaller microaggregates, POM, MAOM[a]	250 µm	50 or 53 µm	Jastrow (1996), Lobe, Sandhage-Hofmann, Brodowski, Preez and Amelung (2011), Pulleman et al. (2005), Six et al. (2000, 2004)
			20 µm	Tisdall and Oades (1982), Totsche et al. (2018)
Small microaggregates	MAOM[a]	50–53 µm	20 µm	Lobe et al. (2011)
		20 µm	–	Totsche et al. (2018)
Silt-sized aggregates	MAOM[a]	50–53 µm	2 µm	Virto et al. (2008, 2010)
		20 µm	2 µm	Lobe et al. (2011)
Clay-sized aggregates	MAOM[a]	2 µm	–	Chenu and Plante (2006)

[a]MAOM contains silt- and clay-sized aggregates, organo-mineral clusters, and primary organo-mineral complexes.

RESPOSTAS CONTRASTANTES DE MOP E MOAM PARA FATORES DE MUDANÇA GLOBAL

Estudos controlados com resíduos

Resíduos de qualidade inferior

MOP

Resíduos de qualidade superior

MOAM

RESPOSTAS CONTRASTANTES DE MOP E MOAM PARA FATORES DE MUDANÇA GLOBAL

Efeitos de aquecimento no solo

ABORDAR OS DESAFIOS DE MUDANÇA GLOBAIS USANDO O QUADRO MOP VERSUS MOAM

- Estratégias de gestão:

Sequestro;

Funcionalidade.

- Problemática:

Diminuição do efeito estufa;

Fertilidade do solo.

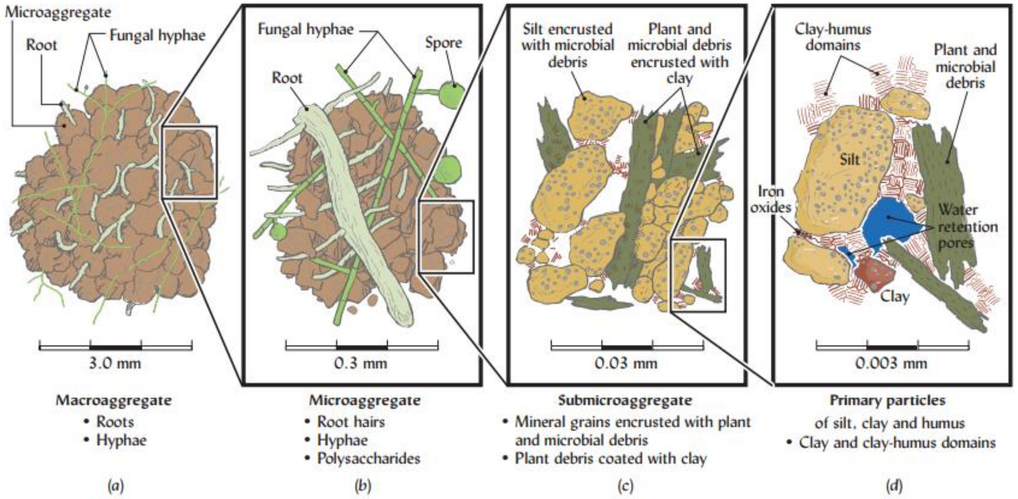
ABORDAR OS DESAFIOS DE MUDANÇA GLOBAIS USANDO O QUADRO MOP VERSUS MOAM

Quando se trata de sequestro da matéria orgânica, o foco tem sido para a MOAM.

Até que ponto isso é viável?

A MOP pode ser sequestrada a longo prazo.

O sequestro depende de outras variáveis, como a interação com outros elementos.



Fonte: R. Weil & N. Brady, 2017

RELAÇÃO: MOP, MOAM E NITROGÊNIO

MOP	MOAM
❑Maior relação C/N;	❑Menor relação C/N;
❑Maior complexidade química;	❑Menor complexidade química;
❑Microbiota usa de forma menos eficiente;	❑Microbiota usa de forma mais eficiente;
❑Reciclagem do N com menores perdas.	❑Pode provocar maiores perdas de N.

ABORDAR OS DESAFIOS DE MUDANÇA GLOBAIS USANDO O QUADRO MOP VERSUS MOAM

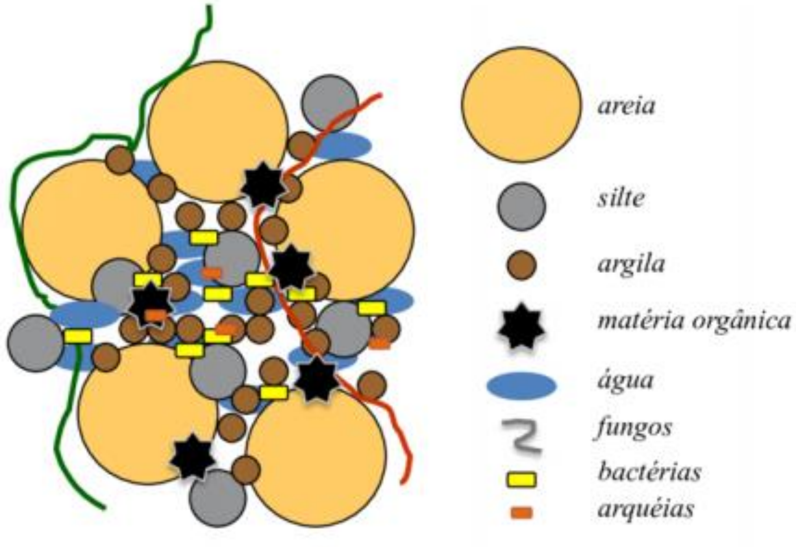
Como gerir a problemática sequestro da material orgânico com fertilidade do solo?

“Dilema do carbono”

Sítio Nazareno. Foto: Elves Barreto, 2019

AGREGADOS DO SOLO

Agregados do solo são conjuntos de partículas minerais que, ao se ligarem à matéria orgânica, formam pequenas estruturas



Composição e organização do agregado

Resultado de diversos processos:

I. Processos biológicos

ii. Processos físicos

iii. Processos químicos

Responsável por proteger o carbono disponível no solo da oxidação

AGREGADOS DO SOLO SÃO INDICADORES?

São indicadores precoces de mudanças ambientais, em particular o uso da terra e a perturbação do solo

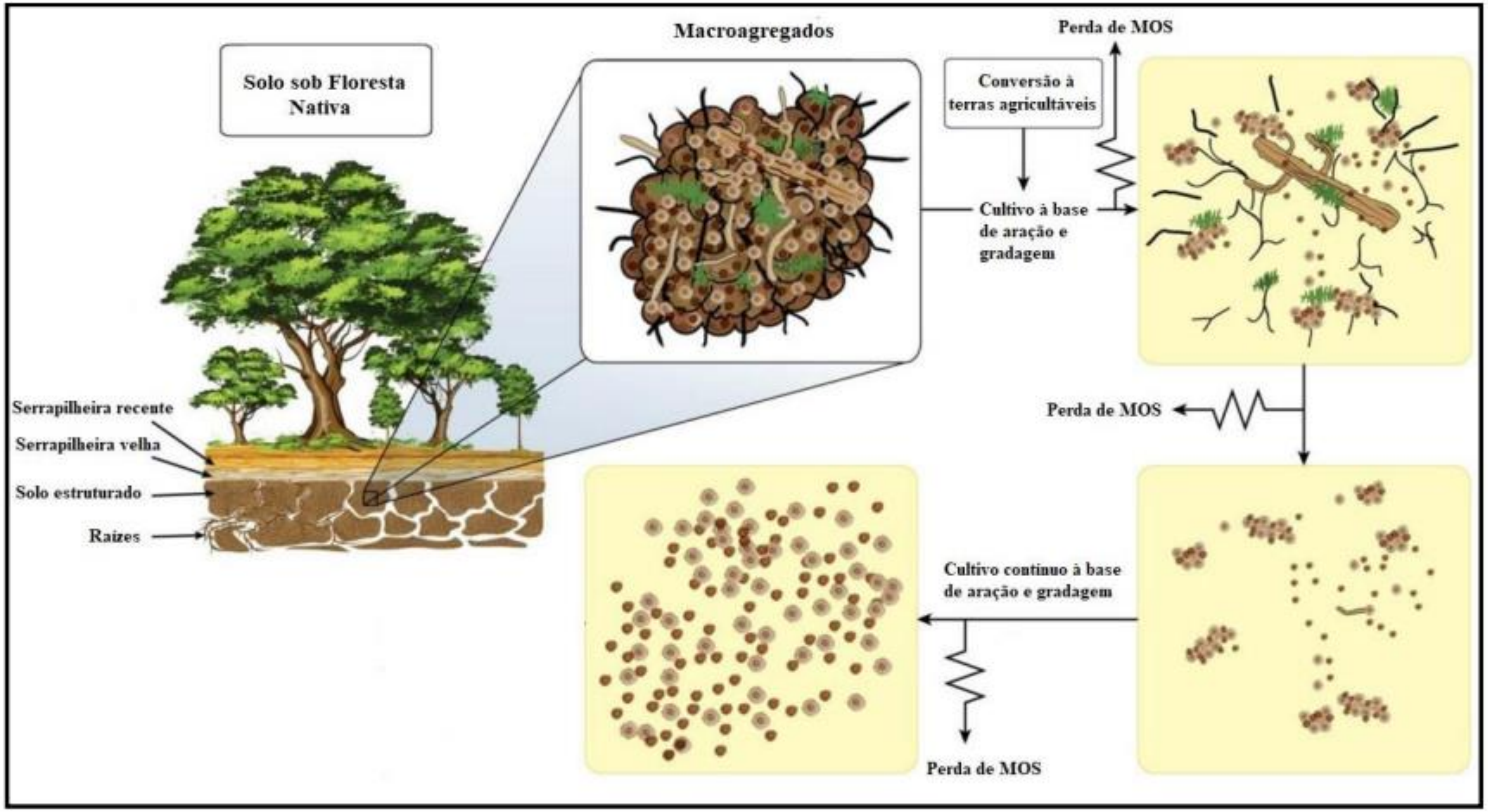


Fig. 1. Exemplos de Plantio Convencional (PC); Em A, tratores fazendo a aragem do solo e em B, a compactação presente no solo ocasionada sob manejo convencional.

Fig. 2. Exemplos de Sistemas de Plantio Direto. Detalhe para a preservação da cobertura vegetal

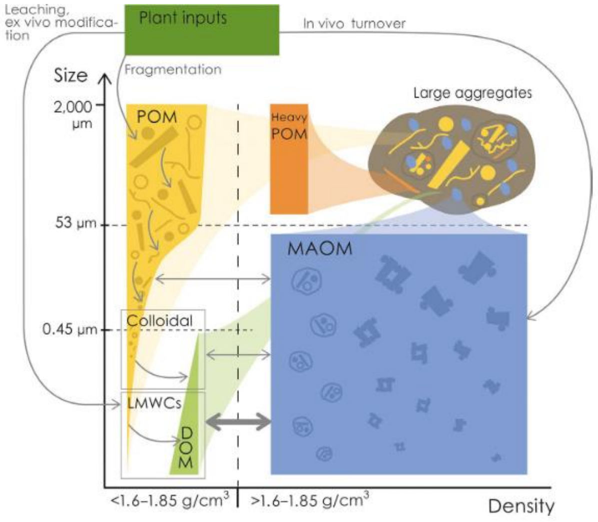
Figura 1. Diagrama esquemático adaptado do modelo conceitual elaborado por Tivet e colaboradores que ilustra o efeito da conversão do uso da terra na agregação do solo e na dinâmica da MOS.43 A conversão da vegetação nativa para o preparo agrícola baseado em arado e gradagem rompe os agregados do solo, promove a dispersão das partículas de argila e microagregados (silte + argila) e diminui a formação de novos agregados.

O QUE É HIERARQUIA DOS AGREGADOS?

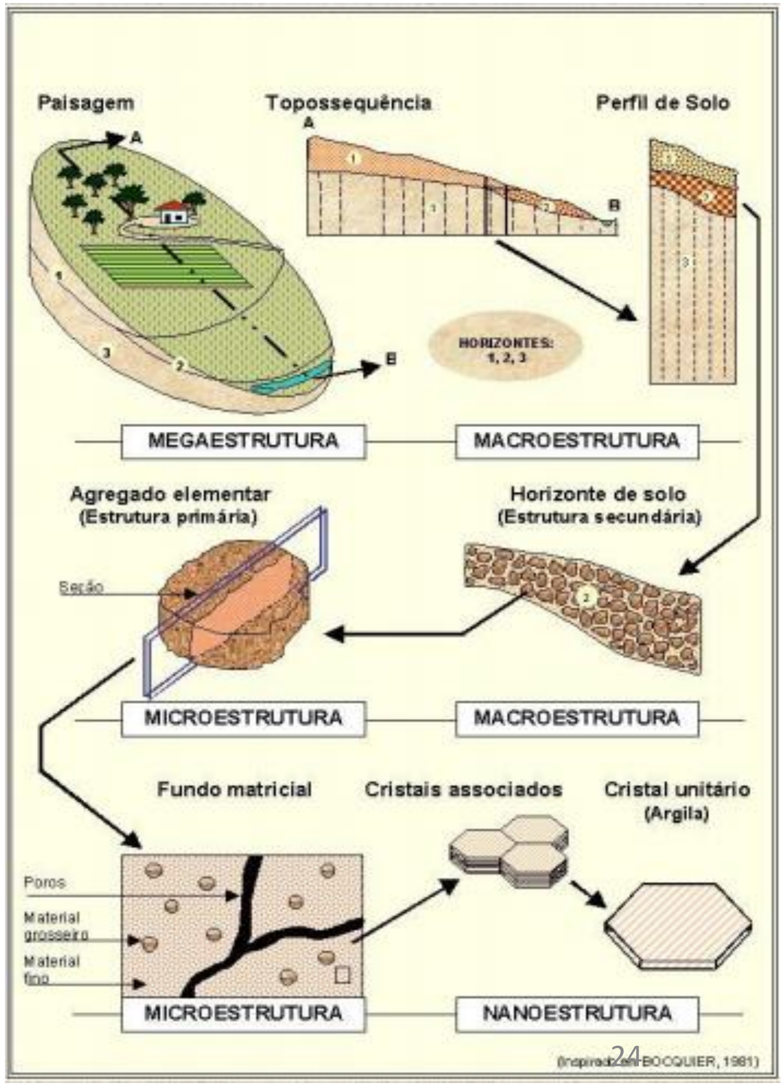
São Agregados de vários tamanhos que interagem entre si de maneiras complexas

Agregados se formam em torno de agregados menores e facilitam a formação de agregados menores

Como resultado, agregados maiores (> 50 µm) contêm misturas de POM, MAOM e agregados menores todos sujeitos a diferentes níveis de proteção contra a decomposição



Sequência Hierarquia de Agregados



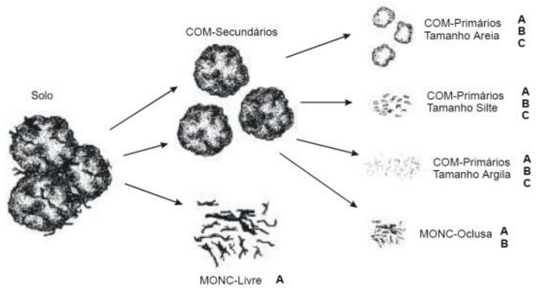
MOP E MAOM SÃO FRAÇÕES COMPOSTAS?

POM e MAOM são frações compostas quando não são completamente uniformes em termos :

i. Química

ii. Taxa de rotatividade

iii. Vulnerabilidade a perdas



POM x MAOM

Separação relativamente simples produz dois componentes MOS altamente contrastantes em termos de

Formação, Persistência e Função

DETALHAMENTO DO MECANISMO

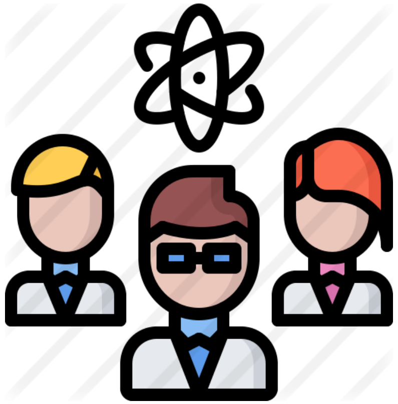
A estrutura POM x MAOM pode não ser detalhada o suficiente para permitir novas idéias ou avanços na pesquisa

Nível de detalhe apropriado para necessidade atual de identificar padrões gerais em grandes escalas comerciais e enfrentar os desafios das mudanças globais

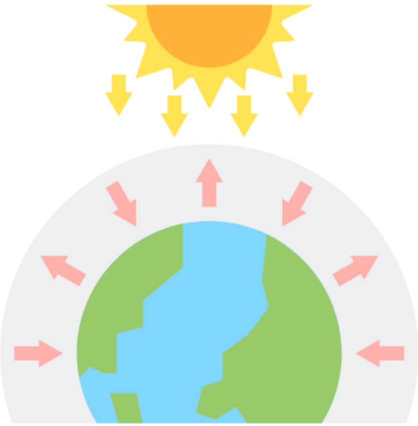
Sugerem que os pesquisadores apresentem resultados amplos das frações POM e MAOM, seja fazendo uma segunda separação ou combinando dados de frações menores que compõem POM ou MAOM

Aplicação de Recomendações Práticas

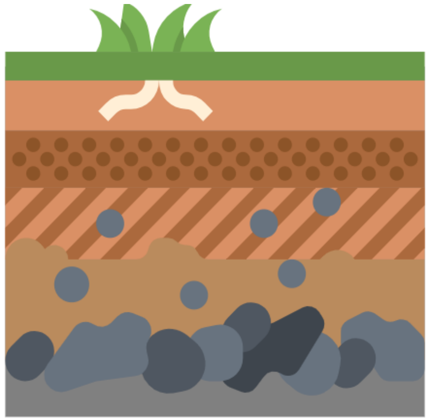
IMPORTÂNCIA DO FRACIONAMENTO MOP E MOAM



Comunidade Acadêmica



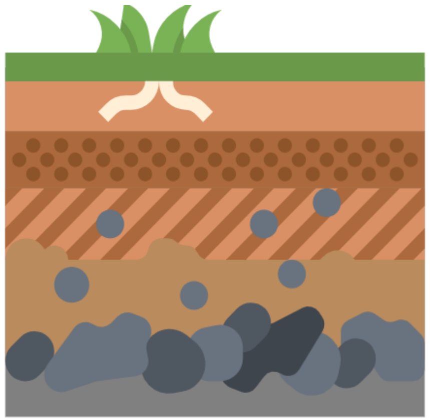
Mudança Climática



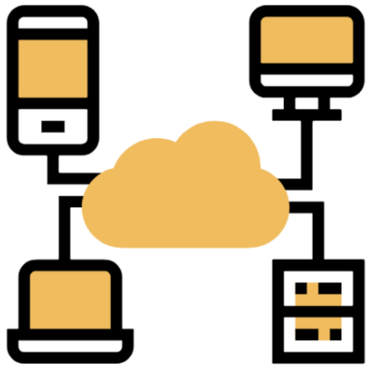
Separação ***pools*** da MOS

MOS

IMPORTÂNCIA DO FRACIONAMENTO MOP E MOAM



Estudos Separação
pools da MOS



Modelagem
Banco de dados

Definição de melhor
estratégias de
manejo

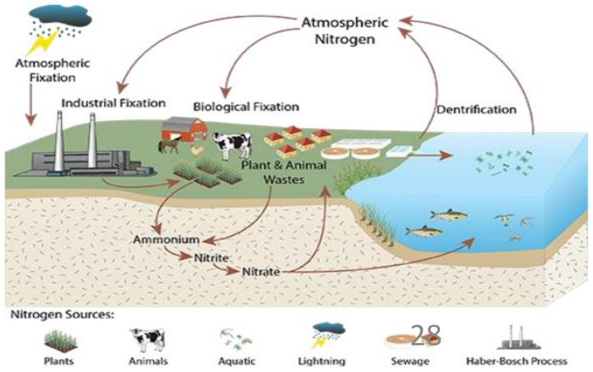
Estratégia bem sucedida de sequestro de C terão como alvo POM e MAOM, podendo levar em consideração:

i. Estrutura microbiana

ii. pH

iii. Disponibilidade de N

iv. Nível de saturação do MAOM



IMPORTÂNCIA DO FRACIONAMENTO MOP E MOAM

Perdas de MOS

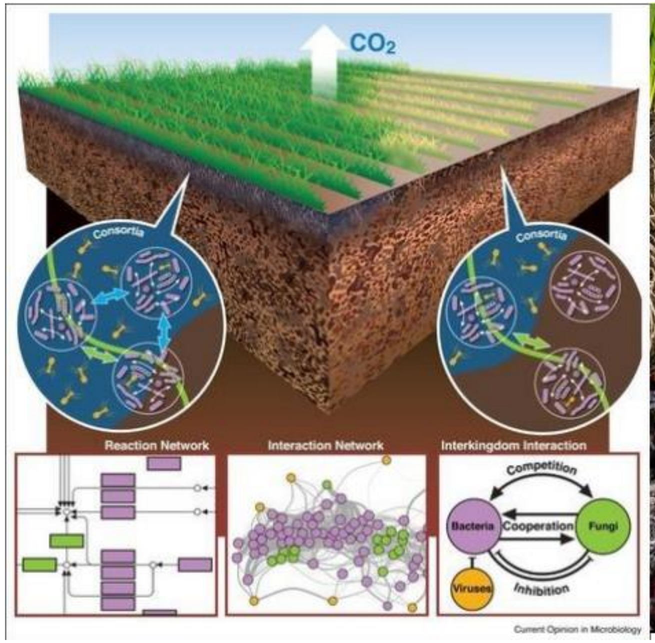
Sequestro e
Acúmulo de MOS

Práticas de Manejo

Estudos

Efeito priming

Mineralização do N



Fauna do solo também contribui para a formação de POM e MAOM

CONCLUSÃO

i. Há pouco consenso entre os cientistas em termos de recomendações específicas para definir soluções para mudanças globais;

ii. estrutura POM versus MAOM é a melhor maneira de conceituar os resultados dos estudos do MOS, identificar drivers e prever mudanças de estoque MOS;

iii. Estrutura POM x MAOM como a melhor maneira de entender e prever a dinâmica de SOM em larga escala no contexto dos desafios de mudanças globais e fornecer recomendações necessárias aos gerentes e formuladores de políticas.

OBRIGADA

DÚVIDAS?

REFERÊNCIAS

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